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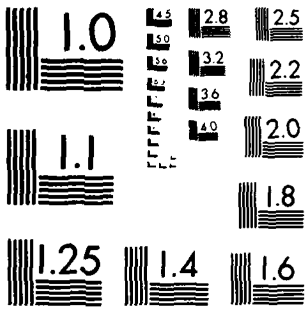

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IDA/OSD RELIABILITY AND MAINTAINABILITY STUDY

Volume II: Core Group Report

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November 1983

Prepared for
Office of the Under Secretary of Defense for Research and Engineering
and
Office of the Assistant Secretary of Defense
(Manpower, Reserve Affairs and Logistics)

IDA

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This report is in four volumes: Vol. I, Executive Summary; Vol. II, Core Group Report; Vol. III, Case Studies Analysis and Vol. IV, Technology Steering Group Report. Study results were derived from case studies performed on eight existing weapon systems and from working groups that examined sixteen individual technology areas. Specific R&M recommendations are made in the following eight areas: Technology Base R&M Programs; R&M Demonstration Programs; FSED Planning and Analysis; R&M Standards; FSED Management Awareness of R&M; (contd)

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John R. Rivoire
Director

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CONTENTS

ABBREVIATIONS

A^3	Affordable Acquisition Approach
A/C	Aircraft
AFB	Air Force Base
AFIT	Air Force Institute of Technology
ALCM	Air-Launched Cruise Missile
ALMC	Army Logistics Management Center
AMS	Airborne Maintenance System
ATE	Automated Test Equipment
ATF	Advanced Tactical Fighter
ATPG	Automatic Test Program Generation
BCS	Bench-Checked Serviceable
BIT	Built-in-Test
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacture
CND	Cannot Duplicate
DARCOM	U. S. Army Materiel Development and Readiness Command
DoD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
DSB	Defense Science Board
DSMC	Defense Systems Management College
ECP	Engineering Change Proposal
ESS	Environmental Stress Screening
FDIC	Fault Detection/Isolation Code
FIT	Fault Isolation Test
FMEA	Failure Mode and Effects Analysis
FOT&E	Follow-on Test and Evaluation
FREQ	Frequency
FSD	Full-Scale Development
FSED	Full-Scale Engineering Development
HARDMAN	Hardware-Manpower Trade-Off
HR	Hour
IC	Integrated Circuit
ICNIA	Integrated Communications/Navigation/ Identification Architecture
IDA	Institute for Defense Analyses
IOC	Initial Operating Capability
IR&D	Independent Research and Development
ITC	Intern Training Center

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I. SYNOPSIS

A. BACKGROUND

In recent years there has been a rising concern about DoD's ability to keep weapon systems both modern and combat-ready. At any given time the availability of many of these systems has been below that needed to maintain the required force posture. The seriousness of this problem was highlighted in the report of the 1981 Defense Science Board (DSB) study of the Operational Readiness of High Performance Systems. One of the major recommendations of that study was to design reliability into the systems from the start and mature that capability prior to full-rate production. The 1981 DSB study also highlighted problems with diagnostics and recognized that increasing system complexity, while not incompatible with readiness, made it imperative that the Department of Defense (DoD) demand and manage acquisition to achieve readiness requirements.

Because of the well publicized problems in reliability, readiness and support, DoD put improvements in this area high on its priority list. The Carlucci initiatives directed at reforming the acquisition process gave reliability and support considerations a very high priority. As a result there has been a major increase in DSARC and top management attention. On each major program there is visibility at the top on progress in meeting R&M objectives through development, production and in early field experience.

The track record from these efforts is uneven. Many of the more mature technologies have done relatively well in meeting reliability objectives. Newer, fast developing technologies

often have serious problems, however, as do programs with accelerated or compressed schedules. The latter are becoming more frequent due to the Administration objectives of fielding new hardware faster. Thus, there is a major challenge in learning to manage acquisitions on accelerated programs so as to attain desirable R&M objectives. Technology advances are potentially helpful in such areas (e.g., in electronics) by providing opportunities to improve both performance and R&M, provided the problem is attacked in both the technology base and the acquisition process.

In the future, increasing weapon system complexity and rising maintenance costs will lead to demands for higher levels of R&M. A review of the Services' Year 2000 studies identified a common theme calling for more flexibility, more autonomy, more dispersal, and reduced support tail dependency in combat forces. While the validity of the presumptions on which these requirements are based may be challenged, their general thrust is unmistakable.

As a result of these concerns, the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) and the Office of the Under Secretary of Defense for Research and Engineering initiated this study, "Steps Toward Improving the Materiel Readiness Posture of the DoD" (short title: R&M Study) at the Institute for Defense Analyses (IDA) with the purpose of identifying and providing support for high-payoff actions which the DoD can take to improve system design, development and support processes so as to provide quantum improvements in R&M and readiness through innovative uses of advancing technology and program structure (Appendix A, Task Order).

B. OBJECTIVE AND APPROACH

The objective of this study was to analyze the state of current and emerging R&M from two different standpoints: first,

by looking at specific new technologies for their potential contribution to R&M improvement and for the type of problems anticipated in their application; and second, by examining specific weapons system acquisition programs to assess the impact of their program structures on the achievement of desired R&M goals. After consultation with the Services and industry groups, and examination of pertinent reference documentation, sixteen technology areas were selected for study as follows:

Technology Studied	Detailed Results in IDA Record Document
• Artificial Intelligence	D-28
• Cabling and Connectors	D-29
• CAD/CAM	D-30
• Structural Composites	D-31
• Directed Energy	D-32
• Fiber Optics	D-33
• Integrated Systems of Manufacture	D-34
• Manpower, Personnel and Training	D-35
• Mechanical Systems Condition Monitoring	D-36
• Nondestructive Evaluation	D-37
• Operational Software	D-38
• Electronic Packaging and Interconnection	D-39
• Power Supplies	D-40
• Testing Technology	D-41
• Very-High Speed Integrated Circuits (VHSIC)	D-42
• Diagnostics	

Eight relatively successful programs were selected for detailed study to address the issue of program structure. The eight programs selected were as follows:

Program Studied	Detailed Results in IDA Record Document
• APG-63 Radar (F-15)	D-19
• APG-65 Radar (F/A-18)	D-20
• APG-66 Radar (F-16)	D-21
• T700 Engine (BLACKHAWK)	D-22
• ASN-128 Lightweight Doppler Navigation Radar (LDNS)	D-23
• TPQ-36 Radar (FIREFINDER)	D-24
• TPQ-37 Radar (FIREFINDER)	D-24
• SPY-1-A Radar (AEGIS)	

In addition, many other programs and associated reports were reviewed for specific relevant information.

Working groups composed of Service and industry personnel were then formed for each of the technology areas and programs to be studied. Working group activities were coordinated and overseen by an Executive Council Core Group made up of representatives from DoD and industry. All the Services, the Office of the Secretary of Defense (OSD), universities, and over 100 contractors participated in and contributed to the study (see Appendix B for membership in the Core Group and the numerous working groups). More than 300 separate meetings were held, encompassing technology and case study working groups, as well as conferences with senior military officers, government and industrial executives. The findings and recommendations reported represent a synthesis of the quantitative and qualitative analyses these groups performed and the judgments they applied to the results.

C. REPORT ORGANIZATION

The results of the study are documented in the hierarchy of reports shown in Fig. 1.

This volume, the Core Group Report, is a condensed summary of the conclusions reached in the Technology Steering Group Report (Vol. IV) and the Case Study Analysis (Vol. III). In the following sections of this volume the overall findings and recommendations are presented in Section II, and the conclusions from which they are drawn are presented in Sections III and IV. Section III is a summary of conclusions from the Technology Steering Group Report, and Section IV is a similar summary from the Case Study Analysis.

D. RESULTS

Ten specific R&M recommendations in the following three categories are presented in the next section of this report:

A. Technology Base Structuring
   1. Technology Base R&M Programs
   2. R&M Demonstration Programs

B. Program Planning and Analysis
   3. Program Planning and Analysis to Integrate Interdependent Elements
   4. Recent Developments in Program Structuring
   5. R&M Standards
   6. Management Incentives
   7. New System Maturation

C. Areas of Special Concern
   8. Collection and Use of Field R&M Data
   9. R&M Training for Managers
   10. Diagnostics.

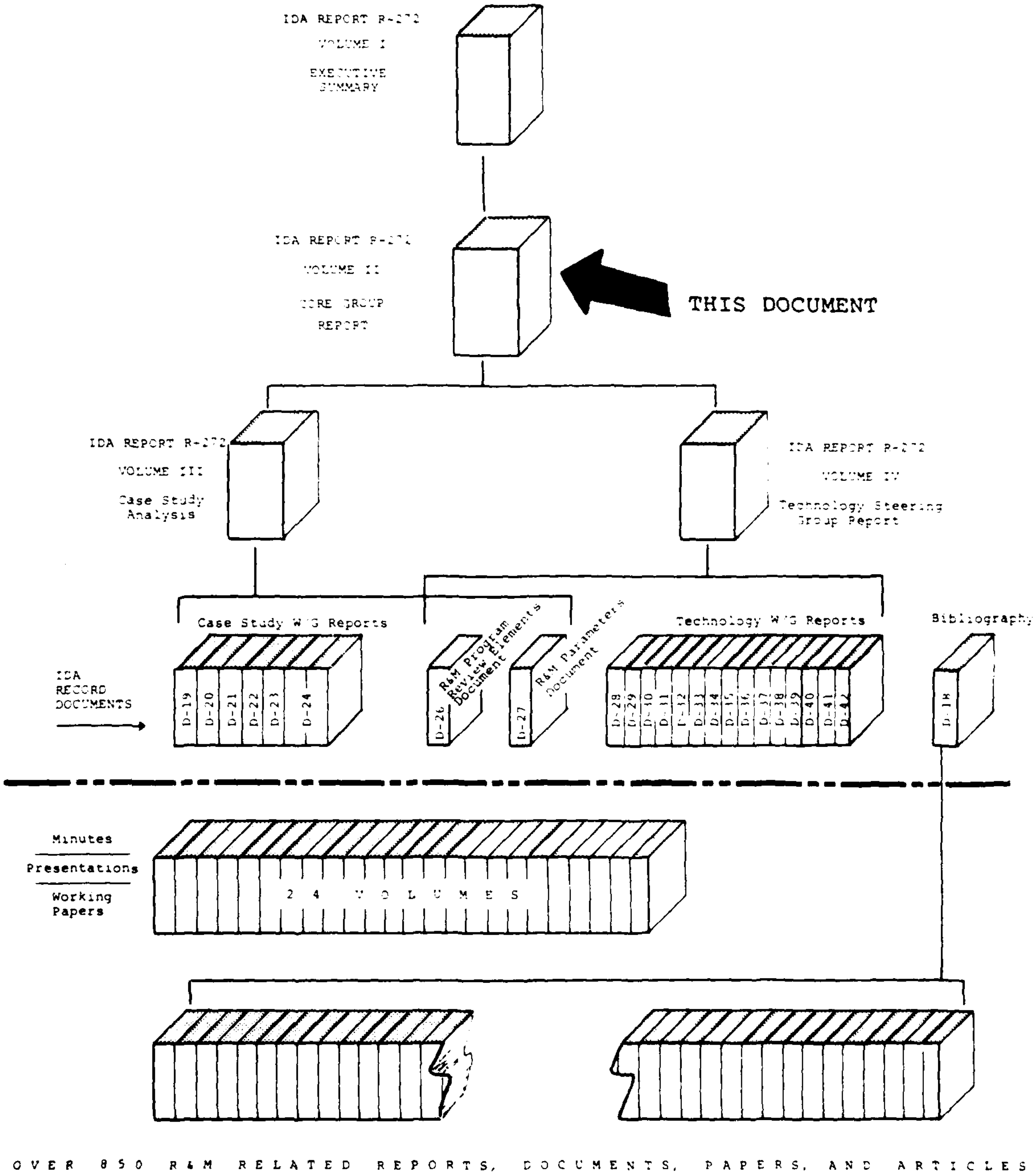

FIGURE 1. R&M Study Report Structure

These recommendations offer fresh opportunities for the application of technology and management initiatives in new areas as well as in areas already well established. As a result of the large-scale participation by both industry and the Services, various actions have already been initiated to use information developed during the course of the work described above. Within the Navy and the Air Force, actions thus far are primarily program-level applications. The Army, however, has initiated, through the Materiel Development and Readiness Command (DARCOM) Headquarters, an action plan that defines tasks to be performed and assigns organizational responsibility for implementing some of the findings of this study (Volume II, Appendix C).

In addition it should be noted that, independent of this study, the Office of the Secretary of Defense (OSD) has established a Logistics Research and Development (R&D) Policy Council charged with giving increased emphasis to R&D in support of logistics needs. The policy decisions of this group are being implemented by a Logistics R&D Working Group consisting of OSD and Service representatives from both the logistics and the R&D communities. Some of the recommendations of this study relate to these new groups.

II. OVERALL FINDINGS AND RECOMMENDATIONS

A. STRUCTURE

These findings and recommendations integrate results of analysis across the disparate fifteen technology reports, seven case studies, and specific information from many other programs and associated reports, as detailed in Vols. III and IV. For convenience, these findings and recommendations are grouped into the three categories of Technology Base Structuring, Program Planning and Analysis, and Areas of Special Concern.

B. TECHNOLOGY BASE* STRUCTURING

FINDING 1: TECHNOLOGY BASE R&M PROGRAMS

Selective expansion of technology base programs directed to improve reliability and maintainability of components, subsystems and systems is needed for current and future military systems.

Comments:

Areas have been identified where additional technology efforts and/or coordination of existing efforts could improve the design data base and associated design alternative selections available to improve the reliability, maintainability, and/or

*The "technology base" consists of R&D programs that are not associated with a system that is in or past full-scale engineering development. In general, these are funded in the 6.1, 6.2 and 6.3A areas, but exceptions occur.

readiness of current or future systems. Identified areas are: Composites, Corrosion, Predictive Techniques, Diagnostics, and Architecture for Reliability (Vol. II, Section III; Vol. IV, Section V). The combination of the expanding use of complex electronic and mechanical devices with embedded computer systems places greater importance on the accuracy and fault-free operation required from diagnostics systems such as built-in test and fault-isolation test (BIT/FIT). This expanding need, coupled with the poor performance of current diagnostics systems, suggests that an immediate and intensive effort is required to resolve this problem (Vol. II, Section III-D; Vol. III, Section IV).

Recommendation:

The Logistics R&D Working Group under the direction of the Policy Council is assembling individual Service plans and an integrated DoD plan for "Log R&D." It is recommended that the Technology Working Group Reports (listed on page I-3) be reviewed by appropriate Service agencies and laboratories as an input to the formulation of Service plans.

FINDING 2: R&M DEMONSTRATION PROGRAMS

There is a need to establish a set of R&M objectives supported by applied technology demonstration programs as an integral part of achieving advanced performance objectives. Such demonstration program plans should include "road maps" which relate the timing of technology developments to their use in the demonstration program. Management must also establish review procedures to ensure timely transition of support technology into weapon systems and support systems.

Comments:

There are insufficient demonstration programs in the technology base aimed directly at R&M objectives or which include

R&M advances along with performance advances. Most such programs are directed primarily at demonstrating improved performance capabilities of components or subsystems even though the potential for significant R&M advances is known and advertized (as in the case of VHSIC). In addition, technical analysis to determine underlying causes of failures is sorely needed to guide technology base development. Technical analyses should be conducted by appropriate laboratories and technology developments identified, "road maps" (for funding and scheduling) developed and prioritized, and target systems for demonstrations identified. This will provide for a more rapid adaptation/ infusion of new technology whereby the technology can be matured off-line and proven acceptable for engineering use separately from specific engineering development programs (Vol. II, Section III-A, B, and C; Vol. IV, Section V).

Recommendation:

The Services should establish, with concurrence of the Logistics R&D Policy Council, a set of quantitative, user-approved R&M Objectives, which in turn can be used to structure quantitative design objectives for advanced technology subsystems and components. The Services should then prepare, and include in their plans given to the Logistics R&D Working Group, a coordinated program of demonstrations, based on technology availability, to reach these objectives. A set of time-based "road maps" to connect technology availability to end-use demonstrations should be constructed.

DoD and Service acquisition responsibilities and procedures should be established to ensure that a structured review of support technology is made at the time of acquisition strategy formulation for each new system in order to determine what support technology is ready for transition.

C. PROGRAM PLANNING AND ANALYSIS

FINDING 3: PROGRAM PLANNING AND ANALYSIS TO INTEGRATE INTERDEPENDENT ELEMENTS

Formalized program planning and analysis procedures are needed early in the acquisition process in order to reduce R&M/readiness risk and to ensure balanced considerations of performance, supportability, budget, and schedule.

Comments:

Year after year studies are performed to ascertain why programs fail or succeed in providing reliable and maintainable systems. However, surprisingly little is known quantitatively about the interdependencies of program activities which affect R&M results. In particular, management-level decisions on funding and schedule adjustments to programs as a whole appear to be made without awareness of R&M consequences. For example, the relationships between front-end funding profiles and the ability to carry out requisite R&M design, analysis, component development, and R&M growth tests are not often addressed in the critical early planning phases. To develop such a discipline approaches to program structure analysis must be pursued with vigor.

The need to emphasize R&M requirements starting with milestone zero and proceeding into the Full-Scale Engineering Development/Production process is spelled out in DoD directives (e.g., 5000.40 and 5000.39), and R&M Program Plans and their various elements are defined in MIL STDs 785 and 470, respectively. It is apparent from this and other studies, however, that implementation of the directives and the R&M Program Plans varies among different types of equipment and different weapon system programs.

There is little doubt that systems with higher reliability are achievable, but the overriding issue is the ability to hold together all key programmatic aspects of the structure when faced with the conflicting demands of funding, schedule, system, and political constraints. While the R&M elements of the acquisition process are generally well-known, the interrelationships and dependencies of elements and subelements are not so well understood. As a consequence, we find cases where management has traded R&M elements for apparent cost reductions and/or improved schedules, but which ultimately has led to overruns, delays, and costly downstream logistics problems.

The management and engineering challenge is to structure an acceptable disciplined approach to planning programs to ensure balanced considerations of performance, budget, schedule, and supportability; and to ensure that the appropriate balance is not lost as the program progresses through its various phases.

The elements of a discipline for planning and analyzing R&M attributes of program structuring were identified during this study. The discipline encompasses considerations for variations in programs and their acquisition environment, how they are structured for R&M, the interrelationships and dependencies of program elements, concurrency and scheduling. It provides the visibility to understand reliability, maintainability, and readiness implications of program structuring (Vol. II, Section IV-A.1; Vol. III, Section IV).

Recommendation:

DoD should issue a "Guide to Structuring a Weapon System Program for R&M," developed by the Services and endorsed by the Joint Logistic Commanders, which includes:

- Emphasis on early incorporation of R&M requirements into engineering design based on specific program structure techniques such as are recommended in this study (Vol.

III, Appendix B) coupled with techniques such as the Navy is developing, and including means for validation testing during development and a formal maturation phase for production units.

- Establishment of a funding profile at the outset of the development phase that supports the development, growth, and maturing of R&M elements in the program structure through FSED and early production. Priorities should be placed on analysis to improve present planning factors and estimates for the cost of R&M activities.
- Firmly established audit procedures to ensure that DoD directives and R&M program requirements are being followed in a consistent and effective manner.

FINDING 4: RECENT DEVELOPMENTS IN PROGRAM STRUCTURING

Whereas the critical elements of a reliability by design approach have come to be known and widely accepted, two elements--computer-aided design engineering and manufacturing (CAD/CAM) and environmental stress screening (ESS)--are rapidly developing and deserve special attention.

Comment:

Rapid evolvement of computer-aided design engineering and manufacturing offer a major opportunity to analyze more completely the R&M features of the design prior to commitment to hardware. To achieve this potential requires a strong commitment to develop the needed data bases and to integrate comprehensive analysis capabilities into CAD/CAM systems. Industry progress and intentions in this area are mixed.

Environmental stress screening has gone through rapid evolution. A wide variety of approaches are being practiced which differ substantially in intensity, cost and payoff. (Vol. II, Section IV-A.2; Vol. III, Section IV).

Recommendation:

OSD and the Services should sponsor a task on computer-aided design and engineering for R&M in order to establish the criteria, a requirements approach and the funding needed to rapidly achieve the potential R&M improvements through design and design analysis.

A policy should be established that ESS must be applied to all acquisitions. DoD should fund sufficient promising ESS approaches to define a consistent set of ground rules for specifying requirements and for evaluating contractor proposals.

FINDING 5: R&M STANDARDS

Advancing technology and the current emphasis on R&M point to the need for improvements in specific R&M standards.

Comment:

A recurrent theme from the R&M study group reports is the lack of adequate standards in certain areas particularly related to electronic or electromechanical systems where there are currently rapidly changing technologies. These are also areas where there are current R&M problems in the field. In addition, deficiencies were noted in human factors R&M requirements, and in the design specifications for reliable use of composite materials. Increased emphasis should be placed on reviewing and updating R&M standards and specifications, particularly in the areas of testing procedures, packaging standards, human factors standards, power supply design, composite materials use, connector standards (including fiber optics), and software design. A further deficiency is that current program standards do not include the early field growth and maturation phase as a requirement. As a result this critical phase is often underfunded and ad hoc in nature. (Vol. II, Section IV-A.4; Vol. III, Section IV-A).

Recommendation:

It is recommended that a Tri-Service Board be convened to develop a specific implementation plan to review and update within the next 24 months standards and specifications for electronic or electromechanical systems, specifically related to:

- Testing procedures
- Packaging standards
- Power supply design
- Software design
- Connector standards (including fiber optics)

and, more generally, human factors standards and composite materials design specifications as they relate to R&M requirements. Further, responsibility should be assigned to revise the R&M program and supporting MIL-Standards to formalize the requirement for a planned maturation phase.

FINDING 6: MANAGEMENT INCENTIVES

There is a need for enhanced management awareness of R&M requirements by both industry and government managers during the acquisition process.

Comment:

In the design and development process many competing pressures have to be balanced, and R&M requirements are often relegated to a lower priority than they were given in the initial planning. High levels of contractor management participation in R&M were evident in all the cases in which R&M was deemed a success. Contract incentives have proven to be an effective way to ensure contractor management attention to R&M requirements. Additionally, contractors respond to perceived DoD priorities. An increased understanding by DoD managers and engineers of the critical elements of R&M programs, how those elements relate to one another, and what they contribute to R&M success would

facilitate communications with contractors that would lead to improved program structures. The Services should then be better equipped to monitor program efforts to meet R&M requirements during the acquisition process (Vol. II, Section IV-A; Vol. III, Section IV).

Recommendation:

It is recommended that the Military Departments be required to prepare and report to the Defense and Service Systems Acquisition Review Councils (DSARC/SSARCs) their plans for contractor incentives related to R&M requirements at each major milestone of the acquisition process. In addition, any proposed reallocation of funds initially programmed for R&M elements, particcularly those designated for component and subsystem growth testing, should be reported along with projected adjustments in R&M achievements and schedules.

FINDING 7: NEW SYSTEM MATURATION

The use of new and evolving technology in system development requires a planned and funded R&M maturation phase that begins early in system development and continues until several years after a system is fielded.

Comment:

It should be recognized that when systems are first fielded they generally are not fully developed, i.e., they are still subject to failure from unforeseen conditions due to design deficiencies or unspecified operational demands. In spite of the best design and manufacturing efforts, there still remain significant unknowns that cannot be detected and addressed until a system is being operated and maintained in the field by the actual user. An exception may be spacecraft, where extensive use of redundant systems and elaborate testing is undertaken in the development/production process to ensure failure-free

operation. For most systems, however, particularly if potential failures are not seen to be life-threatening, the expense of such elaborate design and testing is not justified, provided a well-organized product improvement program is carried out (Vol. II, Section IV-A.4; Vol. III, Section IV).

Recommendation:

R&M growth and maturation programs for major equipments should be included early in program management plans and carried through to satisfy field operations. Such programs should include rapid feedback of field failure data, use of contractor personnel for investigation and establishment of product improvement changes, and rapid approval of corrective measures. Failure data should also be fed to the appropriate Service laboratories (see Recommendation 8). Where appropriate, equipment could be bailed back to the laboratories for extensive testing. The program should continue until the system has satisfied user expectations.

D. SPECIFIC AREAS OF CONCERN

FINDING 8: COLLECTION AND USE OF FIELD R&M DATA

Current methods of collection, analysis, and dissemination of field R&M data are not sufficient to identify underlying causes of failure and thus facilitate reliability, maintainability, and/or readiness improvements.

Comment:

Every working group involved in this study implicitly or explicitly identified a need for better information on the cause of failures in the field (Vol. II, Section III; Vol. IV, Section V). The normal data produced by the maintenance data collection systems usually does not provide the kind of

information needed for engineering analysis of failures. Wide variations in the results of using data from the same data base have been observed in the course of this study (Vol. III, Section IV-B). The commercial sector is far ahead of the military in the collection of accurate data, as is demonstrated by the grocery-store laser beam bar-code reader. In contrast, the current military data systems rely mostly on the handwritten input of maintenance technicians, or in some cases, special data collectors. What appears to be needed is a two-fold approach which involves routinely funding contractor data collection and analysis for design feedback during early fielding, coupled with application of low-risk information technologies to improve the accuracy of data collection and to flag problems for detailed investigation by experts. The DoD laboratories should be involved in this effort. (Vol. II, Section IV-B; Vol. III, Section IV).

Recommendation:

The Military Departments should initiate programs to improve the accuracy and the coverage of current maintenance data systems by exploiting low-risk information systems technology. Lead laboratories should be designated for field data analysis in major technology areas and should be supported to initiate research studies of generic problems, in order to expand the technology base data available to designers. Contractors should be routinely funded to analyze field R&M problems on new equipment.

FINDING 9: R&M TRAINING FOR MANAGERS

There is a real need to upgrade the level and scope of R&M training throughout DoD and to relate it more closely to current manpower skill levels.

Comment:

Analysis of the case studies indicates that contractors do respond to perceived DoD priorities. One factor that contributed to contractor perception of the importance that DoD placed on R&M was the capability and knowledge of DoD personnel on R&M-related items.

Currently, R&M training is provided by a number of separate DoD Service schools, contractors and educational institutions, but it is fragmented and limited in scope. As a result, it is essential that more attention be focused on the educational process and that current DoD educational bodies take steps to coordinate and improve the content of their acquisition management, reliability, maintainability, and design courses. This training will lead program managers to understand the consequences of their respective programmatic decisions (Vol. II, Section IV-C; Vol. III, Section IV).

Recommendation:

OSD should assign executive agent responsibility for R&M training to an existing organization with instructions to work closely with all DoD training institutions in developing a comprehensive, coordinated R&M curriculum.

FINDING 10: DIAGNOSTICS

Diagnostics and in particular built-in-test could become the weak link in the support chain if substantial efforts are not mounted now to codify requirements, design, verification, and maturation processes.

Comment:

Weapon systems have become heavily dependent on built-in diagnostics to indicate subsystems and units which must be replaced. Major problems have occurred on a wide scale in

achieving accuracy and low false alarms. A substantial increase in spares costs and unnecessary repairs results.

Problems in acquiring systems with diagnostics that work span the range of precision in requirements, and environment, design practices, verification and demonstration approaches, and maturation. Solution to diagnostic system problems has been hampered by fractionation of design, test equipment, and human factors efforts. Thus the trade-offs between built-in and external diagnostics are not well established. (Vol. II, Section IV-A.5; Vol. III, Section IV).

Recommendations:

DoD should assign responsibility for development of a set of MIL-Standards for diagnostics specification, design, development, verification, and maturation under the unifying umbrella of an overall program plan. These efforts must be supported with full-time personnel and adequate resources.

The Services should fund efforts to collect and analyze field data on military and civilian systems with extensive built-in diagnostics to quantify relationships between diagnostic performance (detection, isolation, false indications, errors) and support system effectiveness.

III. CONCLUSIONS FROM THE TECHNOLOGY STEERING GROUP REPORT

The findings and recommendations presented in Section II are drawn partially from the Technology Steering Group Report (Vol. IV of this study report), which is a summary of the 15 Technology Working Group reports. Their conclusions are presented here in more detail under four major headings: Technology Base R&M and Demonstration Programs, Specific Interdependencies, The Discipline and Structure of R&M Management, and Research Thrusts.

A. TECHNOLOGY BASE R&M AND DEMONSTRATION PROGRAMS

As discussed in Volume IV, Section IV, there are known deficiencies in the maturity of certain technologies in the technology base which restrict our ability to improve system failure rates and our ability to maintain system performance now and in the future. "Off-line" maturing is required to address these deficiencies. The need is to mature a whole class of new technologies for the purpose of reducing failures, minimizing their impact on operations, and reducing the effort necessary to perform maintenance.

There are three essential features of "off-line" maturing as it is proposed.

- A set of technologies should be matured in a manner which reflects their interdependencies (Appendix C, Vol. IV).
- The target chosen to provide the measure of success both in performance and R&M should be as realistic as possible, if not improvement to an existing system.
- The results achieved should be generalized so that they may become the new level of acceptable performance.

There are a number of approaches to this "off-line" demonstration method. One approach is presented in the form of technology road maps which indicate the task and cost schedules for maturing electronics, structures, and propulsion technologies (Figs. 2-4). These road maps integrate the improved R&M, deployment and sustainability requirements associated with Year 2000 goals,* interdependency requirements, and technology needs identified in the technology working group reports. The road maps are organized to reflect the expert opinions of the individual working groups as to what needs to be done, when it should be done, and in some cases how much it can be expected to cost. These road maps are not presented as a prescription for success but instead represent a point of departure for each service to use in structuring its own activity.

*The year 2000 goals are set forth in Service studies described in Vol. IV.

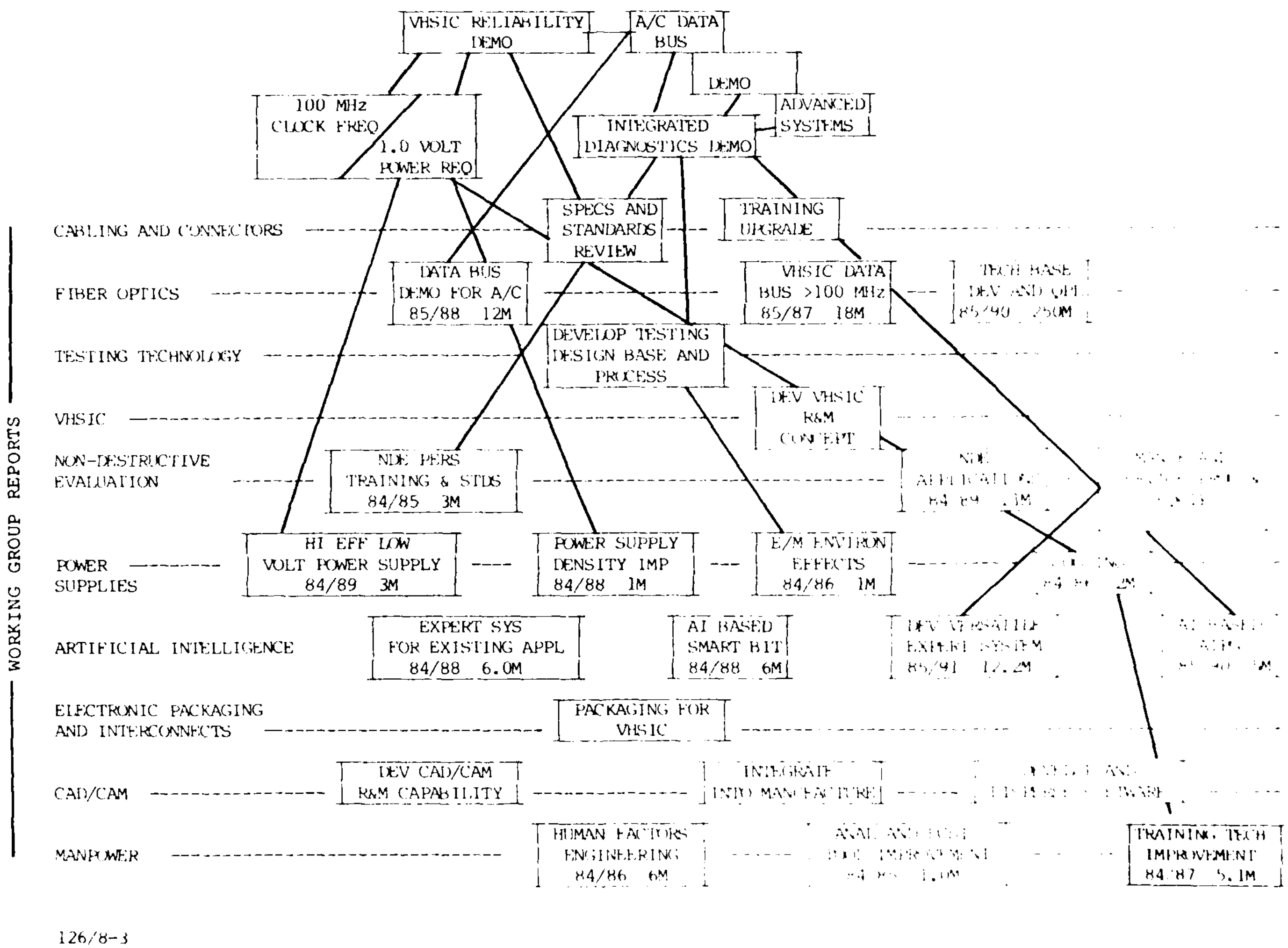

FIGURE 2. Electronics Road Map

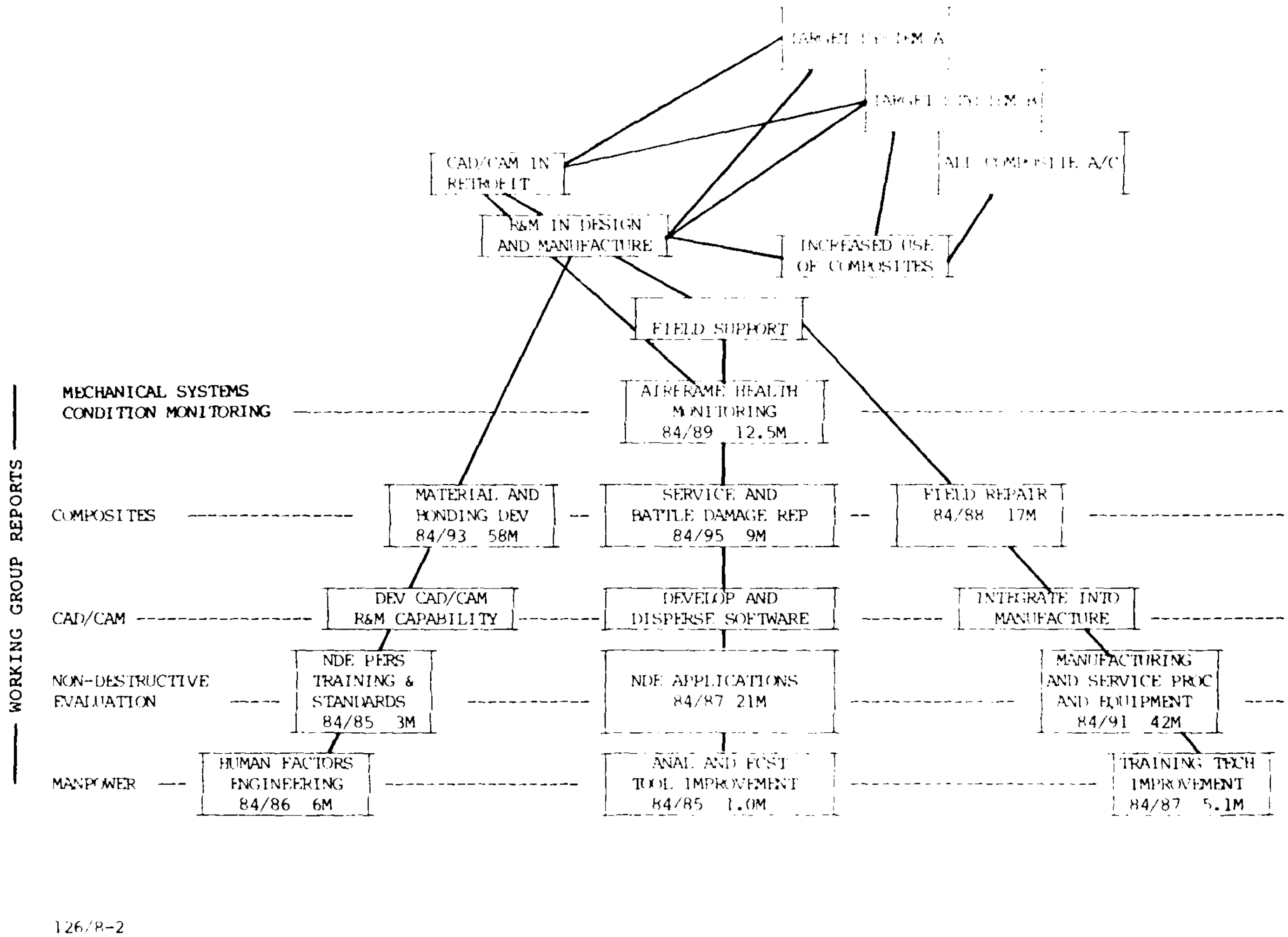

FIGURE 3. Structures Road Map

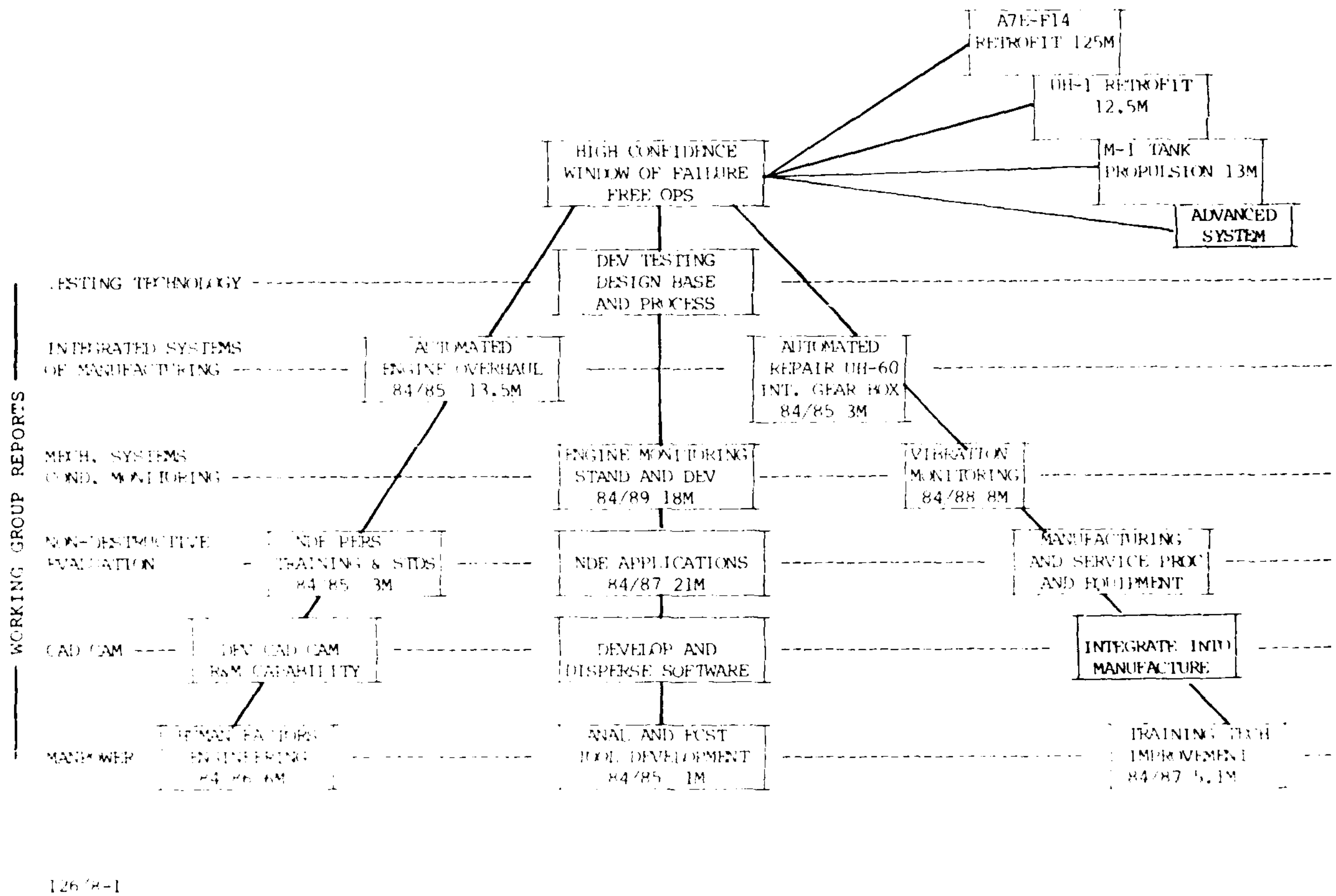

FIGURE 4. Propulsion Road Map

B. SPECIFIC INTERDEPENDENCIES

Many of the topics that the study explored fall into the category of the "overlooked or unexamined assumptions" in decision-making (Appendix C, Vol. IV). The results of these oversights are presented here.

The management challenge posed by technology interdependency is to change the priorities accorded to individual technology developments. The approach proposed is to establish technological performance targets that unequivocally draw the attention of everyone in the system to their importance and that, if pursued, will bring a number of other factors into the right perspective. Four such targets are presented:

1. Establish an alternative to the existing interconnect technology to cope with the 100 MHz clock frequencies of the ICs of the 1990s, and provide system level structures to enhance control of equipment status and reconfigurations.

2. Provide reliable, efficient power supplies for electronics capable of delivering the 1-volt high-amperage DC power required by VLSIC/VHSICs with power densities in the 10 W/in.^{3} range.

3. Establish high-confidence estimates of "failure-free" periods of performance for critical military subsystems. This requirement is an extension of the ability of health monitoring systems to capture incipient failures so as to allow weapon systems to continue battle action prior to cycling them back to a repair facility. (This capability is presently more mature for mechanical systems than for electronic systems).

4. Identify all the implications of the increased use of composite materials in the structures of military platforms. This need is brought about by the constantly increasing use of composite materials in military systems. The side effects of this evolution create new design requirements and challenges for platform and electronics design engineers.

The concept of technology performance targets, when combined with the strategic goal of "off-line" maturing, results in road maps for the conduct of research and development (Figs. 2-4).

C. THE DISCIPLINE AND STRUCTURE OF R&M MANAGEMENT

The techniques of establishing requirements and structuring them to achieve the desired fielded capability are often flawed. Past efforts often resulted in requirements for unrealistic performance levels based on applications of new technology evolving from the technology base but without sufficient knowledge of the associated reliability and support requirements. The result has been fielded systems that fall far short of original expectations.

The need to change this situation is highlighted by the arrival of the "system on a chip." The complexity of modern systems such as directed energy devices or super computers, whose structures appear as collections of imbedded, highly complex subsystems, presents the possibility that feasibility may be driven by system reliability concerns. There will have to be early considerations during the R&D process as to how these imbedded subsystems relate to one another. The Directed Energy Study (IDA Record Document D-32) addresses this type of problem.

One further claim can be made for the early consideration of reliability and maintainability. A common theme of these studies was that the kinds of considerations that can lead to successful proof of concept often are the same as those that would lead to savings in downstream costs (i.e., life-cycle costs). In several instances such awareness has existed. However, due to the way in which priorities have been set in the evolution of these systems, key elements were often given superficial treatment. One of the reasons for this oversight is that the consequences of a design decision are presently not known until much later in the life of a system. Thus, the fault, when it does occur, is buried deep within the design and seldom corrected; a band-aid or patch is introduced as the only realistic option available at the time the fault is finally recognized.

The study found that there were widely differing skill levels in dealing with these problems. As a result, there are various straightforward criteria which could be used by OSD to determine whether or not the broad interests of the DoD are being met. In Fig. 5 the shaded boxes highlight those areas where deficiencies were noted in each report.

D. RESEARCH THRUSTS

The fifteen working group reports indicated a number of research topics which in the aggregate point to six lines of scientific inquiry. In each of these lines of inquiry, a significant amount of detailed research and effort should be actively pursued. The areas are: composites, manpower, corrosion, predictive techniques, diagnostics, and architecture for reliability.

1. Composites

Increased use of composites will highlight additional deficiencies in our scientific understanding of these materials.

	Artificial Intelligence	Cabling & Connectors	CAD/CAM	Composites	Diagnostics	Directed Energy	Electronic Packaging	Fiber Optics	Integrated Systems of Manufacturing	Manpower & Training	Mechanical Systems Condition Monitoring	Non-Destructive Evaluation	Operational Software	Power Supplies	Testing Technology	VHSIC
Are the full set of R&D efforts identified?				■		■				■	■	■		■		
Are DOD & commercial efforts coordinated?	■						■							■		
Are manpower requirements established?	■			■		■					■					
Are demonstration projects established & properly guided?			■		■			■			■					
Is management experienced? Are services coordinated?	■	■	■						■	■	■	■	■			
Are adequate advisory mechanisms established for SPO/PMA?							■					■		■	■	
Are specs, stds & guidelines adequate?	■	■		■	■		■	■				■		■	■	
Are incentives adequate?			■	■				■	■			■	■	■		
Are USARC/SSARC criteria adequate?																■

FIGURE 5. Deficiencies Identified by Working Group Reports
(Deficiencies are indicated by shaded boxes)

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Research into adhesives and the bonding of different materials underlies many of the potential issues. This is another area where attention should be sustained to ensure that adequate resources are applied for a significant period of time.

2. <u>Manpower</u>

The research base underlying the design trade-off process, especially for human factors, has been and continues to be deficient. The importance of continuing and expanding this base of knowledge is increased with the advent of more imbedded complexity and the forecast patterns of demographic change.

3. <u>Corrosion</u>

Corrosion has historically had a severe impact and promises to continue as an important failure mechanism in the advanced-technology systems of the next two decades. A new focus on this age-old issue is necessary to support corrective actions for the anticipated problems.

4. <u>Predictive Techniques</u>

A number of physical phenomena explain the chain of events that precede a failure. The material science discipline is leading the way to making understanding of those phenomena applicable to the management of failure in mechanical systems, potentially achieving a sufficient alert to allow for preventative repairs to be scheduled. There is an analog in electronic systems that is not being adequately addressed. The precursors to electronic failure and schemes to detect them could lead to enhanced diagnostics and an improved ability to estimate the time to failure of a component or system.

5. Diagnostics

In the context of this study, diagnostics are addressed for both electronic and mechanical systems. For electronic systems, the primary emphasis has been in the area of automatic built-in test, fault-isolation test and related testability issues. For mechanical systems, the emphasis has been on condition and health monitoring and nondestructive evaluation techniques.

During the era when discrete components were used in quantity, it was possible to probe electronic assemblies to isolate failures. Now there are layers of hermetic seals and programs stored in memory that obscure the technician's view into the physical processes of system operation. The whole discipline of diagnostics is in a state of flux caused by the rapid advance of hardware complexity behind the interface. The research base should be reassessed to ensure that the various disciplines that could contribute to the solution of the diagnostics problem are properly funded (see Case Study Analysis, Volume III).

6. Architecture for Reliability

The need to understand new concepts for fault tolerance and automatic reconfiguration is latent throughout this study. Now that systems on a chip are feasible, it is possible to reconsider redundancy and other schemes of isolating component failures from system failures. The theoretical basis for various schemes needs to be strengthened. The array of ongoing research tasks should be addressed to determine what in addition could be undertaken. As an example, non-Von Neumann architectures or multiprocessor data flow machines for computers may have uniquely different failure schemes from the present-day systems.

IV. CONCLUSIONS FROM THE CASE STUDY ANALYSIS

Additional findings and recommendations were drawn from the Case Study Analysis, Volume III of this study. It was concluded there that high-payoff R&M actions are currently known that must be planned for and retained in the weapon system acquisition process and programs. These are discussed below under the following headings: Structure to Manage Interdependent Program Elements, Reliability Design Tools and Processes, Off-line Maturing of Subsystems and Components, R&M Growth and Maturation, and Diagnostics. In addition, findings were made in the areas of Information and Education as they relate to R&M concerns.

A. HIGH PAYOFF ACTIONS IN THE ACQUISITION PROCESS

1. Structure to Manage Interdependent Program Elements

a. Observations: The R&M elements of the acquisition process are well-known; however, the interrelationships and dependencies of elements and subelements are less well understood. As a consequence, management decisions have traded away R&M program elements for small cost and/or schedule savings up front, which ultimately led to costly overruns, schedule delays, and downstream logistics problems.

b. Findings: The management challenge posed by the interdependency issue is to structure a single acceptable disciplined approach to planning programs to ensure balanced considerations of performance, budget, schedule, and supportability. Once

programs are so structured, the discipline must provide for continuing analysis and monitoring to ensure that the appropriate balance is maintained as the program progresses through its various phases.

This disciplined approach must also recognize the dependency relationship among the program elements. For example, good reliability predictions depend on a good definition of how the hardware will be used and subsequently, a good environmental analysis. These dependencies result in many elements being "necessary" but few (or none) being "sufficient" in and of themselves, to achieve satisfactory or ultimate performance. The structured process may have more than one path to success but numerous paths exist that will lead to problems that will result in unsatisfactory reliability or maintainability.

c. Action: The Services should analyze and develop a disciplined for managing interdependent program elements including appropriate data bases and parameters and include these in their acquisition strategy.

2. Reliability Design Tools and Processes

a. Observations: Design actions must identify and balance the stresses on various elements of the equipment. Reliability design tasks include environmental estimation, stress analyses, part selection and part derating. These tasks, in combination, define (or estimate) the operating environment of the equipment, predict the stress on the individual part or component, select a part that can operate effectively in that environment and, in the case of most electronics items, derate the part to provide a margin of safety between the rated stress and the estimated operating stress. These activities are fundamental to producing a reliable design. CAD has the potential to make R&M a part of the mainstream design engineering by including R&M as a design requirement and having integrated R&M design capabilities.

Even if R&M design procedures are improved it must be expected that most types of manufactured items will initially have some part and workmanship defects. To prove out manufacturing processes before fielding, environmental stress screening (ESS) is needed. The ESS approach is to apply thermal, electrical and mechanical stress to precipitate failure of the weak parts and assemblies in the factory and thereby result in improved reliability in field use. All the electronics case study programs used ESS to some degree (see Fig. 6). There was considerable variation in the details of the applications, but all programs benefited from improved reliability. Other studies have shown that ESS reduces manufacturing costs and significantly improves productivity, because of reduction in rework and associated retesting. Dramatic increases in operational reliability, due to ESS, e.g., some more than 10 to 1, were also documented (see Fig. 7).

b. Findings: The findings for ESS and CAD are as follows. The design system needed is computer-aided design (CAD) supported by an R&M data base and tied to computerized R&M and logistics analyses. Integration of R&M tools and analyses into CAD will provide design engineers the disciplined use of specialized knowledge in real time with potentially dramatic reductions in cost.

In much the same way the integration of computer-aided manufacturing (CAM) with CAD can enhance both design and manufacturing. Integrated CAD/CAM can provide designers with knowledge of manufacturing constraints which can lead to a more consistent production process.

The ESS approach should be developed during the design and development phase. ESS should be employed on test hardware so that expensive tests are not delayed due to design and workmanship problems. Results should be analyzed to provide information needed to refine screens prior to beginning production. The ability to adjust, add or delete screens is necessary to achieve the ultimate ESS benefits.

	F-15 RADAR	F-16 RADAR	F/A-18 RADAR	FIREFINDER RADAR
PARTS	IC's & HYBRIDS	IC's & HYBRIDS	IC's & HYBRIDS	IC's & HYBRIDS
MODULE	YES	YES	YES	CONSIDERING
UNIT (OR BOX)	YES (4 OF 9 LRUs)	YES (1 FAILURE-FREE CYCLE)	YES (3 FAILURE-FREE CYCLES)	SELECTED UNITS
SYSTEM	YES 24 OP HRS (3 FAILURE-FREE CYCLES)	NO	YES 25 OP HRS (5 FAILURE-FREE CYCLES)	YES 100 HRS (25 FAILURE-FREE CYCLES)

FIGURE 6. Stress Screening Use

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- ARN-84 TACAN

FIELD MTBF	200	(Before ESS)
FIELD MTBF	2000	(After ESS)

  - DEPOT REPAIR COST AVOIDANCE   \$5M/YR
  - SPARE REQUIREMENTS REDUCED

- UNIT COST OF EQUIPMENT TO SERVICE UNCHANGED

- YEARLY REPAIR SAVINGS = 6% OF PURCHASE PRICE

FIGURE 7. ARN-84 Reliability Improvement due to ESS

ESS applied during early production serves as a "find-and-fix" program in which manufacturing process problems and some latent design deficiencies are identified and corrected. Stress screens should be determined after consideration of the process controls which can prevent introduction of manufacturing defects and after evaluation of test and inspection approaches. Stress screens should not be used in lieu of possible preventative action, since preventative action is almost always less expensive and usually results in a more reliable product.

The reliability potential of ESS is so significant that it warrants special attention. All electronics development and production programs should require ESS. ESS applications should be described in a plan and must be dynamic in nature and structured so that maximum screening effectiveness is obtained. Cost models, yield and rework data and failure data should be maintained to demonstrate effectiveness of the program. Periodic reports showing the status of screening results should be provided to management.

c. Action: DoD should invest in CAD systems and in ESS approaches that address R&M problems in order to mature and understand their use. Demonstration programs should be selectively funded and carefully evaluated. Also, a policy should be formulated to ensure ESS is applied to all acquisitions.

3. "Off-Line" Maturing of Subsystems and Components

a. Observations: Within a total weapon system program context, the off-line maturing of system and subsystem elements offers significant risk reduction for today's concurrent program environment. The T700 engine program represents a classic example of successful off-line development and insertion into a program with provisions for maturation (see Fig. 13).

b. Findings: In addition to this observation from the T700 program, the technology portion of this study recommended three essential features of "off-line" maturing that are re-emphasized here. The first is that a set of technologies should be matured in a manner which reflects their interdependencies. Second, the target chosen to provide the measure of success should be as realistic as possible, if not improvement to an existing system. Third, the results achieved should be generalized and become the new level of acceptable performance. From a programmatic point of view, the management issue becomes one of when is the technology ready for program insertion and what actions will minimize the risk of doing it. There is no simple answer for these questions but the integrated approach to technology maturation discussed in Volume IV, Section V, coupled with evolution of the disciplined structured approach as discussed in Volume III, Appendix B, could result in a significant reduction in risk for new programs.

c. Action: The need for off-line component and subsystem development should be evaluated on each DSARC program as well as on less major systems. Guidelines should be developed for concurrent programs to routinely fund such developments.

The Services should also increase their technology base efforts for programs with objectives such as the Air Force ultra-reliable radar program.

4. R&M Growth and Maturation

a. Observations: Without exception, the case studies showed that despite the best design efforts, problems will be found in development testing, production, and in field use. An example from the APG-66 program is typical (Fig. 8). These facts support the rationale that testing and growth programs are essential elements to producing reliable equipment.

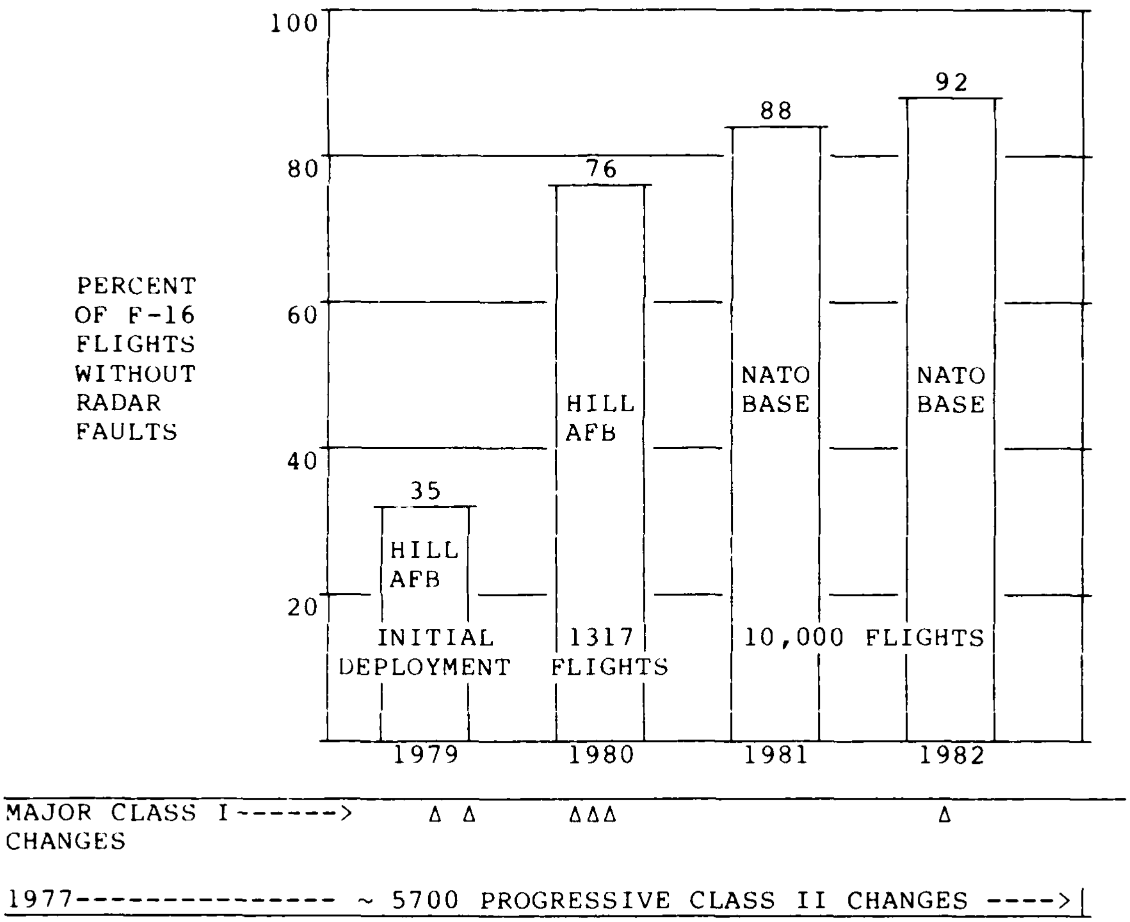

FIGURE 8. Changes Made After Fielding Significantly Increased the Percent of Flights Without Radar Faults

R&M growth programs should be oriented to supplement effective design and manufacturing processes.

A comprehensive growth and maturation program is more than just a test phase labeled reliability growth or reliability development testing. It is a coordinated effort starting in the conceptual phase, influencing the design phase, reaching across the whole test program and extending a reasonable period of time into field use. A well-executed growth and maturation program requires adequate resources for data gathering, data review and analysis, and for engineering manpower assigned to investigate, resolve and correct problems as well as an expedited change processing system to allow rapid incorporation of problem corrections.

It is essential that built-in test (BIT) development be structured to have a parallel growth and maturation program (see Volume III, Section IV-A for diagnostics observations). The BIT in all of the cases studied required a period of concentrated maturation before the BIT performance reached an acceptable level.

It is clear from some programs reviewed that additional classes of problems occur when equipment enters production and again when it enters operational service (Fig. 9). These problems must be identified and corrected, or the system will be plagued with the problems for its entire operational life.

b. Findings: A comprehensive R&M growth/maturation program starts early in the conceptual planning phase, continues through the design phase, influences component development testing and continues into the operational phase. The programs evaluated in these case studies showed only a limited amount of growth planning and testing. The reliability improvement warranty (RIW) programs on the APG-66 and the LDNS were the only planned efforts that extended for any significant time into the operational phase. The following sections will provide perspective on the front-end design effort and the plans necessary to manage a growth program adequately.

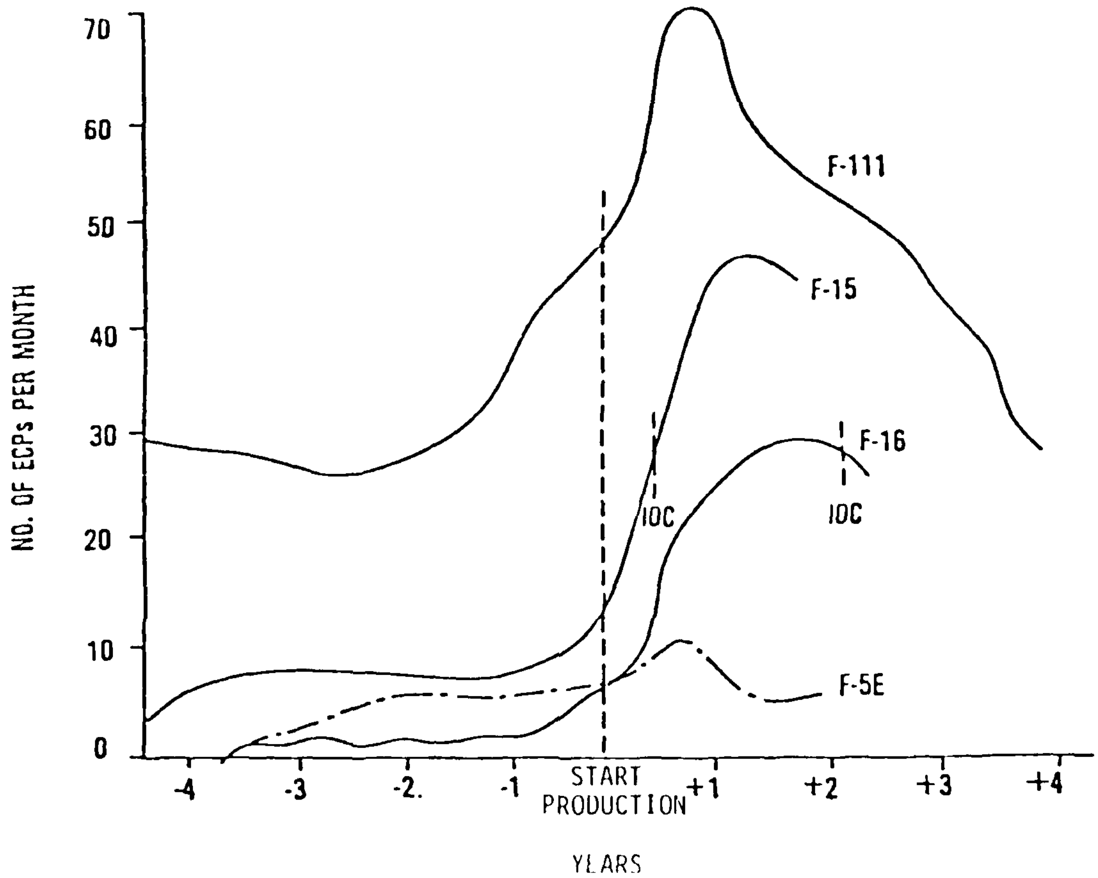

FIGURE 9. Engineering Change Proposal (ECP) Rate

(1) Front-End Design Efforts for R&M

Appendix B to Vol. III identifies the structure for designing R&M into weapon system programs. The R&M elements cited there were considered, to various degrees, in all the case studies evaluated. The results of these studies indicate that the front-end design effort led to higher levels of R&M at the start of the test phase.

(2) Management Environment for R&M Growth

DoD policy and major acquisition contracts should provide for integrated R&M growth programs, with proper incentives for R&M growth. Acquisition programs must improve their responsiveness to engineering change proposals (see Fig. 10 for variances in flow duration). Formal configuration control should be delayed as long as practical. Guidelines should be developed for tailoring management of ECPs during the R&M change introduction process, and these should be taught to managers and enforced at all levels. Programming and budgeting should include resources for this effort.

The growth must start with the beginning of hardware testing and extend two to three years into field operation. A typical growth profile is shown in Fig. 11. A test-analyze-and-fix philosophy must prevail throughout all aspects of a program. Each phase must make efficient use of the test resources.

An accurate and timely failure feedback procedure is necessary to provide the designer with information to accomplish the required corrective action. Achievement of this feedback during early field operation will require on-site engineering support.

(3) Maturing the Support Structure

Today's complex, highly interactive systems require the growth and refinement of the other factors to realize the full

PROGRAM	AVERAGE FLOW CALENDAR DAYS
E-3A	344
E-4	210
Air-Launched Cruise Missile (ALCM)	164
Roland	178
LDNS	5-30

CHANGE INITIATION THROUGH CONTRACTUAL APPROVAL

FIGURE 10. Duration of ECP Approval Cycle

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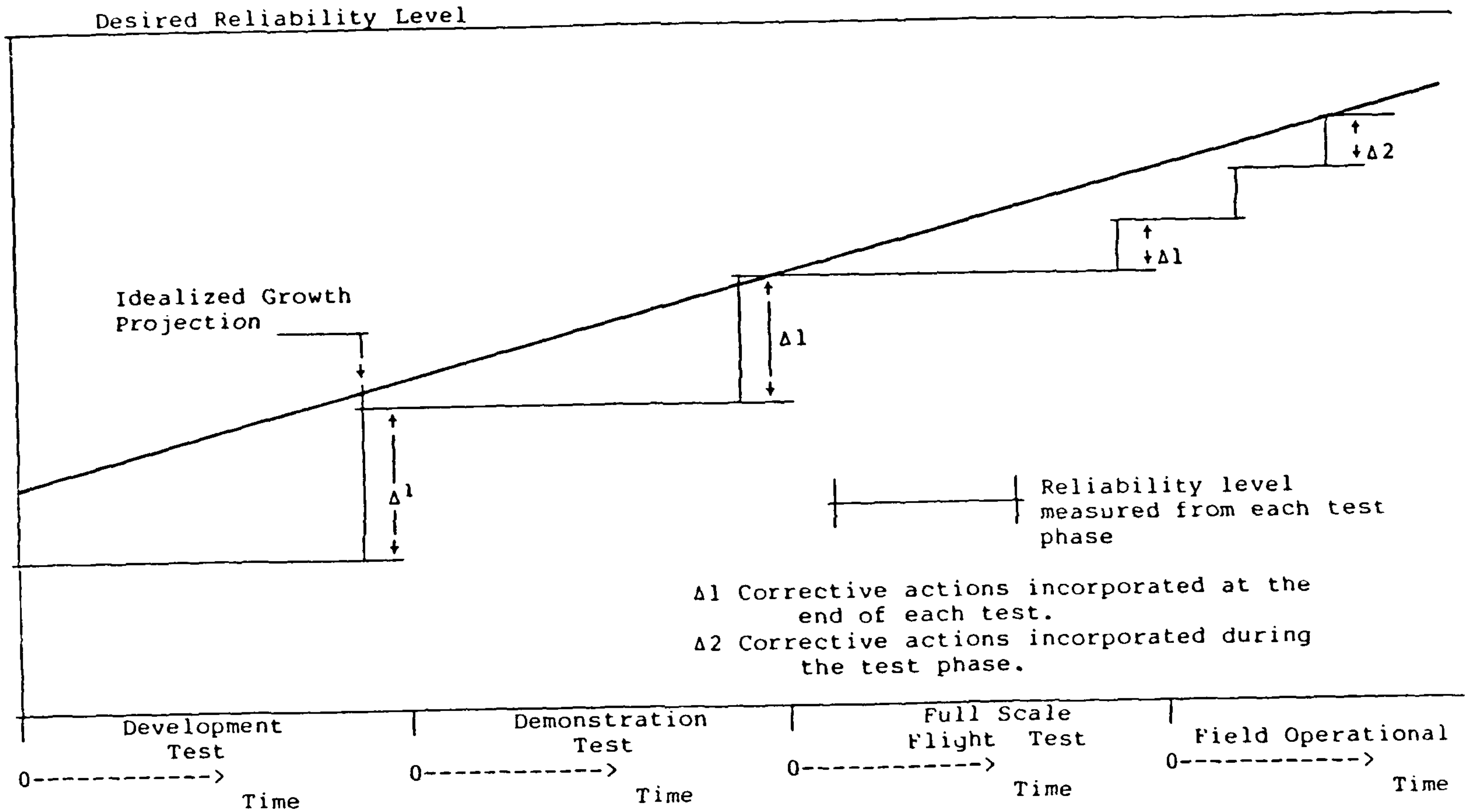

FIGURE 11. Typical Growth Profile

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potential of reliability and maintainability. These factors include: diagnostics, manpower and human factors, training, technical data, support equipment, and software. Very significant improvement in readiness and sustainability can be realized if the total support structure is matured in a systematic way.

(4) Funding

The growth and maturation program for reliability and diagnostics is critically dependent on front-end funding, which must be structured with full identification of the activities discussed above and with particular attention given to adjunct test hardware.

A conceptual view of current versus needed funding profiles is given in Fig. 12. Further analysis would be needed to define the details of an actual funding profile; Figure 12 is intended only to visualize an apparent current problem.

c. Action: R&M Program MIL-Standards should be revised to include a plan for an integrated development and field R&M growth plan.

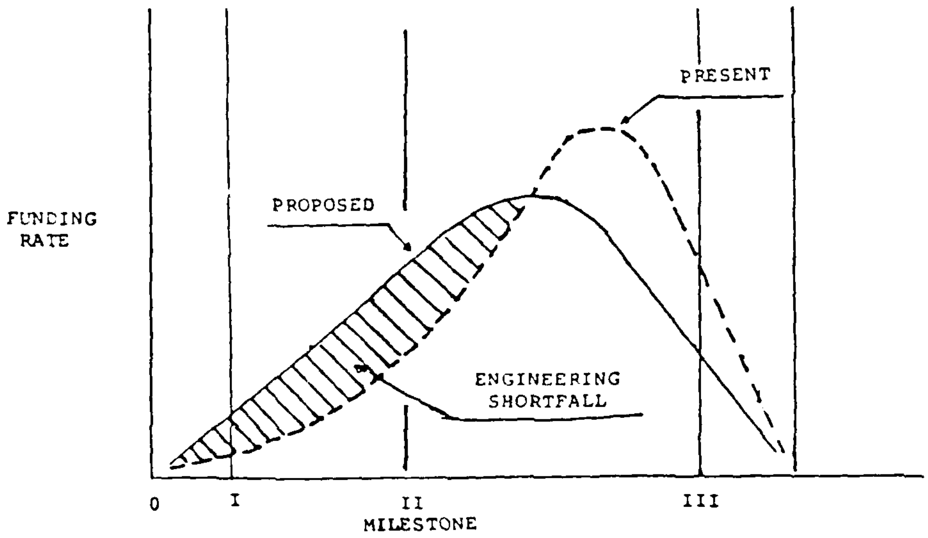

FIGURE 12. Funding Profile for RDT&E

5. Diagnostics

a. Observations: Diagnostic systems development is an immature discipline when compared to reliability. In diagnostics, there are no accepted definitions of requirements that can be used for contracting that are directly understandable to a designer and that can be related to field performance. On the other hand, for reliability, there are design tools for analysis of the stresses that cause failures as well as for predicting failure rates of components, subsystems and systems. Design tools for diagnostics are much less structured and practiced.

In reliability testing, there are proven techniques for simulating the operational stresses an equipment will undergo, weeding out the causes of unreliability and verifying the potential system reliability. Diagnostics testing techniques are much less mature. Though fault insertion tests are performed in the lab, they are poor predictors of field performance. A comparison of results from laboratory fault insertion tests and field operational tests is shown in Fig. 13. It will identify some problems, but success in such a demonstration is no guarantee of a good design. Thus, demonstration by fault insertions are necessary, but not sufficient, to validate a diagnostics design.

Lack of knowledge in the diagnostics area (contracting, statement of requirements, design, testing, deployment) presents a significant challenge to the development community to improve diagnostics of current weapon systems and acquisition methods for improved diagnostics in future weapon systems. Fundamental work is required in all these facets of weapon program development to produce acceptable diagnostic capabilities for field use.

b. Findings: From the case study activities and numerous other studies and presentations reviewed, it is clear that the achievement of a mature diagnostics capability is the result of a defined process. This process encompasses both research and development activities, which are not weapon program specific, as well as the acquisition process, which can be weapon program specific. Achieving effective diagnostics requires a plan, management strategy, motivation, technical activity, and funding that spans system acquisition from initial requirements definition through deployment.

(1) Statement of Requirements

The military user's requirements should address diagnostic capability in the larger context of the operational mission and

MULTIPLEX BUS EQUIPMENT

MEASURE OF EFFECTIVENESS	RESULTS		RATING	
	FAULT INSERTION TEST	FIELD	SATISFYING CONTRACTUAL REQUIREMENTS	AS USER SEES IT
FAULT DETECTION (%)	90	49	SATISFACTORY	DEFICIENT
CANNOT DUPLICATE (%)	--	45.6	--	DEFICIENT
FAULT ISOLATION (%)	93	69	SATISFACTORY	DEFICIENT
RETEST OKAY (%)	--	25.8	--	DEFICIENT

FLIGHT CONTROL SYSTEM TEST (ST)/BUILT-IN-TEST (BIT)

MEASURE OF EFFECTIVENESS	RESULTS		RATING	
	FAULT INSERTION TEST	FIELD	SATISFYING CONTRACTUAL REQUIREMENTS	AS USER SEES IT
FAULT DETECTION (%)	100	83	EXCELLENT	DEFICIENT
CANNOT DUPLICATE (%)	--	17	--	DEFICIENT
FAULT ISOLATION (%)	92	73.6	--	DEFICIENT
RETEST OKAY (%)	--	20	--	DEFICIENT

Source: IDA Paper P-1600, Built-in-Test Equipment Requirements Workshop

FIGURE 13. Typical Fault Insertion Test Results versus Field Results

environment as well as the support constraints of manpower, the skill-level maintenance concept, deployment, and the logistics burden. The requirements, constraints, environment, and economics should then drive the architecture of the system, diagnostics being one of the fundamental characteristics. Significant information improvements are needed for formulating these requirements.

Definitions, terminology, and figures of merit to describe diagnostics requirements have proliferated to the point that communication relative to diagnostics measures is difficult. This is not a trivial problem; it impedes the way diagnostics are specified, managed, designed, tested, and measured. Proposed MIL-STD-XXX, "Testability Program for Electronic Systems and Equipment," and MIL-STD-1309 are useful but not sufficient steps to resolve this problem. Better ways of specifying diagnostics requirements are needed to achieve the readiness and support goals of the Services.

(2) Design

In the area of diagnostics system design, the following needs have been identified:

a. Strategies to minimize cannot duplicate (CND), bench-checked serviceable (BCS), retest OK (RTOK), and false alarm conditions during design.

b. Techniques to maximize vertical testability.

c. A flexible diagnostic system so that changes can be incorporated readily in diagnostic algorithms, screens, and tolerances with minimal hardware impact.

d. Fault-free software development techniques.

e. Techniques to enable more concurrent hardware and software development and earlier integration of the two.

f. Trade-off tools for assessing the diagnostics implications of design decisions on the support structure.

g. Computer-aided engineering techniques for enhancing design for testability in support of proposed MIL-STD-XXX. (Some techniques such as LOGMOD and STAMP may already be able to meet this need, though they are not widely used.)

h. Both the Services and contractors need to develop experienced people who understand how to achieve good diagnostics designs.

i. Tools for predicting, measuring, and managing the diagnostics designs.

j. Better design practices such as control of timing margins in high-speed circuits and systems.

(3) Development and Demonstration Test

Improvements in development and demonstration testing will aid diagnostics development. The following measures have been suggested by experts in the field:

a. Use reliability and other test events as opportunities to discover problems with BIT performance. Environmental testing may be particularly useful for discovering false-alarm indications such as induced intermittents and transients.

b. Increase the number of spare assets and the time budgeted in the system integration laboratory to investigate diagnostic anomalies without impacting the schedule and use of other assets.

c. Expand the set of faults inserted. (Time required for fault insertion tests might have to increase.)

d. Increase the allowable cost of demonstrations to include repair costs. This action will permit the insertion of a better cross-section of faults.

e. Develop a library of computer simulation models to test BIT (hardware, software, firmware).

f. Adopt comparability analysis as a useful tool for identifying a realistic fault set for insertion.

g. Develop and incorporate in MIL-STD-471 improved demonstration techniques to predict field diagnostics performance.

(4) Operational Test and Field Maturation

Field maturation is essential to achieve inherent diagnostics potential. When a system is first fielded, it is common to find that not all the hardware and software provisions of the diagnostics have been fully implemented. In addition, the operational use patterns and the environment produce new failure modes and diagnostics indications. These new indications, which the BIT may not deal with properly, are resolved by the judgment of operators and maintainers (who may not have been trained to deal with them) with the aid of technical data

(which may not have been developed to address them). A structured diagnostics maturation effort is the only way most experts see to bring the diagnostic capability to its full potential. The APG-65 and APG-66 programs are excellent examples of effective BIT maturation. Figure 14 indicates the rate of diagnostics growth of the APG-66 radar during the FSD/production phases. The key features of these programs should be used in structuring future maturation efforts for complex equipment.

c. An Approach to Planning Future Avionic Diagnostics: In addition to the above activities, Appendix E of Vol. III includes an illustration of how a system might be structured to achieve significant diagnostic improvement. This approach is oriented specifically toward avionics, but the thought process should be useful for other applications as well. Regardless of the system type, diagnostics capability must be considered as a fundamental concern in the conceptual phase of system architecture development.

In the world of avionics diagnostics, bold steps are necessary to improve radically performance in the field and reduce substantially the cost of maintenance. Supportability improvements, particularly the contributions of avionics diagnostics, require new approaches to solve the problems faced by the Services in the field today. Technology improvements appear to offer the opportunity to make strides toward such improvement. Advanced architectures provide the means to achieve improved supportability.

d. Action: An agency should be designated to be responsible for developing a structured process for carrying diagnostics through from stating requirements to design, development, test, and maturation. The most natural vehicle for this would be a diagnostic standardization program similar to those started for reliability in the last 10-15 year time period at both DoD

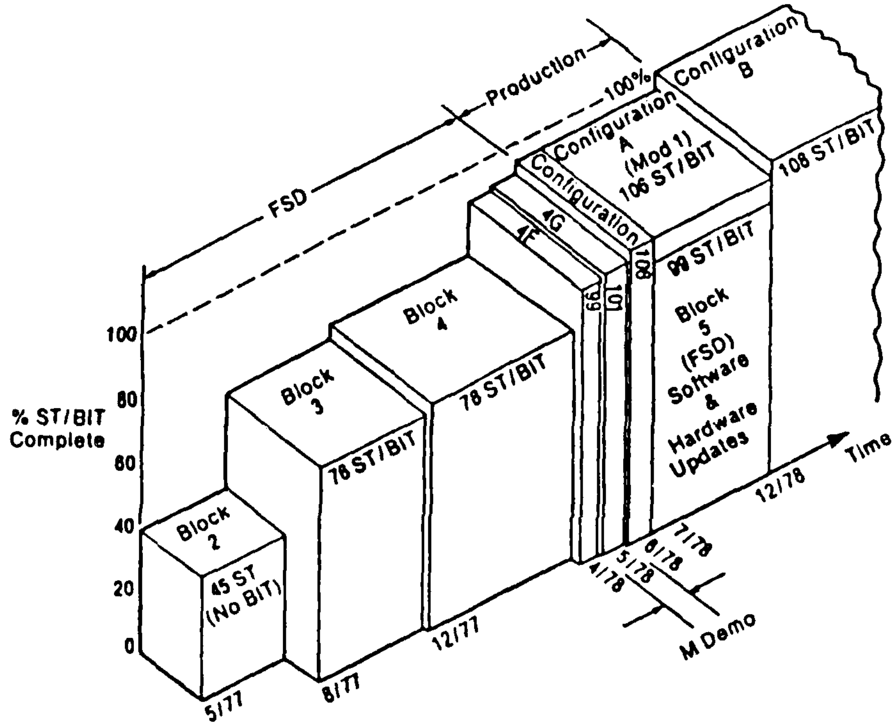

FIGURE 14. APG-66 Radar ST/BIT Growth

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and NASA. In addition, there is need to establish an R&D program to develop the technologies required to solve current problems (false alarm and unnecessary removals).

B. INFORMATION

1. Conclusion

Accurate and detailed engineering-quality information on system and component failures must be provided for identifying and solving equipment problems and focusing technology efforts.

2. Observations

A thorough understanding of how each military Service operates and a comprehensive investigation and analysis of the sources of data are necessary if one is to avoid misinterpreting reported data. Wide variations in results, using data obtained from the same data base and reported in numerous studies and briefings, have been observed in the course of this study. Five examples are provided in Vol. III as follows:

1. Impact of the F-16 fleet electrical modification
2. F-15 and F-16 radar removal data
3. Impact of installation of maintenance data terminals at all F-16 bases
4. Impact of installation of data terminals at Dover AFB for the C-5A
5. T-38 base-to-base comparison of avionics reliability.

Based on analysis of the cases listed above, the following findings were made.

3. Findings

The planned operational concepts, as reflected in the Service Year-2000 studies, and the complexity of current and planned weapon systems, make it essential that data systems be capable of supporting units in combat as well as peacetime, and be user oriented (e.g., Automated Data Entry) for accuracy and speed. The Army SDC system provides a reasonable solution for management uses. The Navy (Air) has an excellent, very flexible query system. The Air Force Automated Maintenance System (AMS) for C-5As is a superb system but only for C-5As. The Navy data system for submarines is very comprehensive and has paid for itself many times over; for example, by providing engineering-quality data to support the extension of overhaul periods. In addition, all of the Services have good systems which provide excellent data during the acquisition process but in many cases the systems are not imposed on the contractor.

In spite of these areas of success in general the current institutionalized data systems are archaic. The data systems are useful only to track trends, and then only when (a) no significant data systems changes have occurred within the trending period and (b) no significant changes in operational scenarios/mission profiles have occurred in the trending period. Data system usage in studies such as this are fraught with problems because of the requirement for quantitative backup for proposed changes/concepts, and hence the requirement to slice the data in ways it is not normally sliced or to make judgment based on incremental differences.

The current military data systems do not provide data that can be used to characterize the R&M performance of a given technology. For example, if one were to try to evaluate the impact of changes from currently fielded solid-state equipments

to VHSIC implementations, it rapidly would become apparent that the data base does not permit one to obtain R&M data at the device level, or by device type.

Contractors and customers require engineering-quality data in order to be able to correctly identify a problem and evaluate candidate solutions from both cost and performance viewpoints. Additionally, it is desirable to be able to monitor performance of an item by serial-number identity, so that the effectiveness of changes under the configuration control system can be evaluated. Under the current maintenance data systems, this is not possible since the data system was not designed to provide such information.

Detailed, accurate data collected during the early operational phase of a weapon system program is critical to improving reliability, maintainability, and readiness. It is unreasonable to expect that all field problems are, or can be, found and fixed prior to operational use of the system. Diagnostics, again, is the toughest area to mature due to the interactions with all aspects of the support structure. Reliability is but one driver of diagnostics. Manpower, human factors, training, technical data, and support equipment all interact with diagnostics to increase the magnitude of the find-and-fix process. Unfortunately, the impacts of many of these elements cannot be assessed until the early fielding phase.

4. Action

Develop and implement policy to ensure that funding and procedures are in place to get engineering quality data to support the planned maturation on specific programs which include R&M growth.

C. EDUCATION

1. Conclusion

Actions to enhance and expand R&M knowledge and experience of DoD and industry engineers and managers must be taken to achieve long-term improvement for full-range weapon system acquisitions.

2. Observations

The cases studied showed that contractors do respond to perceived DoD priorities. One factor which contributed to contractor perception of the importance that DoD placed on R&M was the capability and knowledge of personnel the contractors interfaced with on R&M-related items. R&M have not always been given proper emphasis by engineers, support personnel, and managers. Managers and engineers must understand what the different elements of an R&M program are, how they are interrelated, and what they contribute to R&M success. Additionally, DoD engineers and management would benefit from having access to highly qualified, experienced personnel who could assist them at critical times during program development.

3. Findings

There are several facets to the solution of this problem. One of these is R&M training. R&M training is provided currently by a number of separate DoD Service Schools, contractors, and educational institutions, but it is fragmented and limited in scope. There is a real need to upgrade R&M training throughout DoD and industry.

The need for improved training methods results both from the fact that there is little formal academic means to obtain

the basics of reliability and maintainability skills and that many, if not most, of the current DoD education programs do not provide adequate coverage of the basics necessary for a successful R&M program. Within the case studies, there was an apparent correlation between the assignment of experienced personnel and the relative success of the particular program. How this experience was gained was not examined.

Another facet in the solution to this problem is the establishment of a method of providing highly qualified, experienced "consultants" to the engineers and managers at critical times in the development cycle. Various attempts have been tried by the Services, from the review method such as the Navy Pre-Production Reliability Design Review (PRDR) and Air Force Independent R&M Reviews to more formal assistance teams. When experience is limited, efforts must be made to share it among programs.

One conclusion is that the content and results of the case studies could be used to materially enrich existing educational programs within the DoD. This would not only improve the skills of the R&M and engineering practitioners, but also form a basis for educating program managers and acquisition management executives in the ramifications and implications of the various alternative structures for a successful R&M program.

a. Improving the R&M Capability in DoD. The current DoD work force has not received sufficient training or support in R&M. Under current circumstances it does not appear likely that this condition will change in the future. In fact, the problem is likely to become more serious as technology becomes more advanced.

Fundamental needs for improving the DoD R&M work force competence and performance are divided into four categories--development of DoD work force capability, development of an in-house advice and assistance capability, improvement of contractor relations, and interface with the academic community.

(1) <u>DoD Work Force Capability</u>. There is a critical need to upgrade the competence of the DoD military and civilian work force in the design aspects of R&M. The engineering world is one of constant change. Therefore, the DoD R&M training program must be dynamic and include development of system R&M requirements; management of the acquisition process to optimize system effectiveness and readiness; R&M program management; R&M engineering management; design for R&M; production R&M assurance; and R&M testing and evaluation.

(2) <u>In-House R&M Advice and Assistance Capability</u>. Operational reliability and maintainability problems that are not solved at the source surface occasionally throughout the life-cycle. An in-house cadre of R&M engineering specialists (a quick-reaction team), that can be tasked on short notice to provide advice and assistance or independent opinions on day-to-day operational problems, is a possible solution worth exploring.

(3) <u>Government/Contractor Relations</u>. The best results are obtained through the mutual respect of government/contractor personnel working in a cooperative non-adversarial manner. Likewise within the government environment similar cooperation and the ability to assess R&M activity are important contributors to improved R&M.

(4) <u>Academic Relations</u>. Most college and university engineering curricula concentrate on basic skills and disciplined knowledge. Only a few courses address R&M technology. There is a need for increased communication between the academic community and the R&M engineers and technicians.

b. Current Status of R&M Training and Education in DoD. There are several education and training sources from which DoD R&M engineers may obtain or may have been obtaining job-enhancing technical and management skills, knowledge, and abilities.

(1) Academia. Formal college and university training specifically applicable to the needs of the DoD R&M work force is quite limited. However, some educational opportunities are available to the R&M work force, but the education available is generally introductory in scope and does not provide the opportunity for in-depth education in R&M engineering techniques.

(2) DoD Technical and Professional Training. Within the Department of Defense, a number of schools focus on the technical problem of acquiring new weapon systems:

- Defense Systems Management College (DSMC). The current curriculum of DSMC includes the 20-week Program Manager's Course, a 3-week Executive Refresher Course, and a 1-week Flag-Rank Refresher. These courses include R&M and readiness issues in the general course of instruction as elements of the major case studies and class exercises. Guest lectures by noted authorities in the field are also utilized. This approach places the subjects into context and allows the students to grasp the complexities and interrelationships of the various issues instead of viewing the subjects in isolation. The current approach may benefit from examining the material that has been gathered by the case studies and using this material to update and expand the content of the course case studies and exercises used at DSMC.

- U.S. Army Management Engineering Training Activity (USAMETA). USAMETA is a management training, research,

and consulting organization within the U.S. Army Materiel Development and Readiness Command (DARCOM) and trains 13,000 DoD students per year in short, concentrated management and engineering courses. The current curriculum of 100 courses includes eight which are designed to satisfy expressed training needs for the R&M engineering community within DoD. Several other courses contain R&M subject material. These courses are designed for R&M support personnel and managers from other functional areas.

- Army Logistics Management Center (ALMC). ALMC is a DARCOM school whose mission is to conduct training, perform research, formulate doctrine, and provide information and consulting programs for logistics management matters. The ALMC curriculum consists of 71 courses. These courses are designed for journeymen and managers. With the exception of a specialized Army-peculiar reliability-centered maintenance course, the ALMC curriculum includes no R&M courses. However, many courses include blocks of training on R&M. The DARCOM Intern Training Center (ITC) located at Texarkana, Texas, is a component of ALMC. ITC provides R&M training for two one-year DARCOM Intern Training Programs--the Maintainability Engineering Intern Program and the Quality and Reliability Engineering Intern Program. These programs are designed to assist graduate engineers in making the transition into the Army R&M community.

- Navy Acquisition Logistics Management School. The school educates Navy military and civilian personnel on the current acquisition and logistics policies and procedures. Each one-week class consists of 15-40 program management, fiscal and support personnel. One

session is devoted to R&M and includes an overview of this R&M study.

- Air Force Institute of Technology (AFIT), School of Systems and Logistics. AFIT conducts courses that are designed to provide instruction in systems logistics and management areas related to military and civilian duty assignments. The Professional Continuing Education (PCE) Program consists of approximately 58 courses of relatively short duration--1 to 7 weeks. Course content generally emphasizes the operational areas of systems acquisition and logistics management. As a part of the above curriculum, AFIT offers four R&M courses for Air Force students. The courses address reliability, R&M research and applications, reliability theory, and life-cycle cost management.

- Other Short Courses. Other means also used by the military services for R&M training are contract training and utilization of in-house experts. The Defense Logistics Agency (DLA) and the Navy make extensive use of this approach. Such courses are usually intended to be conducted for some limited time period and/or specialized audiences.

c. Actions. DoD R&M training is currently being provided by a variety of sources, both in-house and contractor. However, there is no organized program to establish and maintain a coordinated R&M curriculum for engineers, support personnel, or managers on a DoD-wide basis. As a result, there is opportunity for nonuniformity in training, overlap in course offerings, and omissions where training may be badly needed. There is a need to integrate R&M training activities throughout DoD.

Two basic alternatives could meet the criteria specified above:

- Establish a new organization with a mission to provide R&M training and related advice and assistance to the DoD community.

- Assign executive-agency responsibility to an existing organization for R&M training. The executive agent could work closely with DoD, academia, and industry training institutions to develop a comprehensive R&M training curriculum.

In addition, consideration should be given to reestablishing Master's Degree Programs in Reliability at schools like the Army's Red River and the Air Force's Master's Degree School, which were the source of valuable, well-trained people.

A P P E N D I X   A

TASK ORDER

68/18-1

OFFICE OF THE UNDER SECRETARY OF DEFENSE

WASHINGTON D C 20301

'ESEARCH AND ENGINEERING

2 April 1982

TASK ORDER
NO. MDA903 79 C 0018: T-2-126

TITLE: Steps Toward Improving the Materiel Readiness Posture of the DoD (Short Title: R&M Study)

1. This task order is for work to be performed by the Institute for Defense Analyses (IDA) under Contract MDA903 79 C 0018 for Manpower, Reserve Affairs and Logistics.

2. <u>PURPOSE</u>:

To identify and provide support for high-payoff actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvements in R&M and readiness through innovative uses of advancing technology and program structure. The DoD objective is to enhance the peacetime availability of major weapons systems and to enhance the ability to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible.

3. <u>SCOPE</u>:

To (1) identify high pay-off areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M or readiness through innovative uses of advancing technology.

The basic questions to be addressed in the study are:

(1) What are reasonable expectations for raising system reliability and maintainability goals, making the best possible use of improved reliability management techniques which have been demonstrated and of emerging maintenance technologies--diagnostics, computer-aided maintenance training, etc.?

(2) What are the estimated utility and costs (in needed additional resource expenditures) of attaining these goals?

(3) To the degree such attainment is worthwhile, how can it best be implemented?

It is desired that the focus of the study be a pragmatic, in-depth review of several of the more successful recent major systems and sub-systems developments, of developing technologies with particular potential for improving maintenance effectiveness and of such recent studies which can contribute to the integration and interpretation of the data obtained. The emphasis should be placed upon the elucidation and integration of the expert knowledge and experience of the engineers, developers, managers, testers and users involved with the complete acquisition cycle of the selected systems as well as upon supporting analysis. The results are intended for possible application, as appropriate, to new weapons systems and sub-systems now in the planning or development stage.

4. SPECIFIC TASKS AND ADDITIONAL GUIDANCE:

a. A review will be made of recently acquired systems and/or sub-systems with perceived above norm R&M, and developed using practices representative of each Service, in order to determine:

(1) What were the R&M objectives and how were they arrived at?

(2) How were the programs structured to meet the objectives?

(3) How did costs, schedule and performance objectives impact the R&M levels that were achieved?

(4) The acquisition, contractual, incentives and funding approaches used.

(5) What engineering approaches were taken and how was technology applied to meet these objectives?

(6) How were the evolving systems tested and what approach was used to correct deficiencies?

(7) What were the effects of reducing the support tail or otherwise simplifying the support structure?

b. Assess diagnostics technologies; specifically, include BIT and ATE approaches used in systems with above norm performance. Also, compare the original estimates of numbers and skills levels of the maintainers required with the actual numbers and skills levels required for these or other systems.

c. Assess the potential impact of new and advancing technology on the recommended approaches for R&M and diagnostics. Recommend how best to exploit this new technology in order to achieve R&M, diagnostic, or readiness improvements. Include the recommendation of innovative support or design concepts that would have significant beneficial impact from the new technology.

d. Analyze and assess the pros and cons of the approaches (particularly contracting approaches, funding, testing, R&M engineering practices) used and develop specific combinations of these approaches or modifications of them that can be applied to various weapon types.

e. Integrate the results into a form appropriate for presentation to a high level joint Industry/Service group whose objective will be to review and develop further recommendations that would lead to the development of weapon systems with improved R&M. The application will be to new weapons systems now in the planning or development stage.

It is expected that a phased approach will be used. The phasing is to permit flexibility in staffing as the nature of the effort changes, to permit meaningful periodic review of progress and results and to permit redirection in approach in response to interim lessons learned. It is further anticipated that extensive use will be made of the workshop approach to ensure combined depth and breadth of review as well as to permit meaningful involvement by the ultimate implementers of study results.

Phase 1--Organization and Planning.

This effort is to develop the basic study rationale, organization and plan of action for review and approval to proceed by the cognizant office and IDA. Available data and information will be gathered and utilized to the degree feasible in achieving the following basic Phase 1 objectives:

(1) Compile and assess R&M figures-of-merit to represent system readiness, reliability, maintainability and support manpower needs, both in peacetime and wartime.

(2) Develop and apply the rationale for selection of systems and/or sub-systems to be studied.

(3) Develop the plan for the organization, staffing and implementation of the study. Specific attention should be paid to the need for tapping the diverse sources of in-depth knowledge which exist among contractors, and Service laboratory, development, test and operational units.

(4) Develop an initial approach to the integration and analysis of the information developed and its application to the development of improved approaches to better reliability and maintenance.

Phase 2--Program Reviews.

For each selected weapons system and/or sub-system program and for technologies selected, carry out the planned study activities to address the issues identified in 5(a),(b). Complete the acquisition of such other data or studies needed for Phase 3. A preliminary report of findings shall be made in October 1982.

Phase 3--Analysis and Integration.

Carry out specific tasks 5(c),(d), analyze the pros and cons of the alternative approaches devised, perform informal structured reviews and critiques with the community of potential implementers of study results. Prepare draft reports suitable for Phase 4.

Phase 4--DoD Review.

IDA is requested to support this effort by:

(1) developing, organizing and presenting the study results, suggestions for high-payoff actions and technical issues to be addressed;

(2) provide technical support to Review Group activities;

(3) summarize the proceedings of the meeting and prepare draft formal recommendations for Review Group review and approval.

Phase 5--Follow-on Study.

As agreed by the cognizant office and IDA, and within funding limitations then existing, carry out recommendations of the DoD Review Group for additional special study activities.

5. SCHEDULE:

This is planned to be a multi-year study. During FY 1982, Phase 1 is to be completed and Phase 2 undertaken. The Phase 1 results are to be completed and briefed to the cognizant office within 90 days of initial staffing of this effort. Interim Phase 2 results, consisting of initial review and analysis of selected programs and a preliminary technology assessment, shall be completed and briefed to the cognizant office by October 15, 1982 and a draft report submitted 30 days thereafter. Remaining schedule milestones will be as approved jointly by the cognizant office and IDA following review of Phase 1 results.

6. COORDINATION:

Throughout the study effort, coordination will be maintained, through the cognizant office, with the offices of Acquisition Management, Assessment, and Tactical Warfare Programs. The cognizant office will provide guidance to the study group as to the nature and form of results judged to have maximum potential value.

7. FUNDING:

$400,000 is authorized to be expended in FY 1982. $400,000 is planned for FY 1983. Complete resource planning is contingent upon review and approval of Phase 1 results.

8. TECHNICAL COGNIZANCE:

The cognizant office for this study is Special Assistant for Weapon Support Improvement (MRA&L).

9. SPECIFIC ADMINISTRATIVE INSTRUCTIONS:

a. If at any time during the course of this task, IDA identifies the need for changes in this task, such as additional resources, schedule modification, changes to emphasis of effort or scope, etc., as set forth in the above paragraphs, a report, with appropriate recommendations, will be submitted in accordance with the terms of the IDA/WSEG Memorandum of Understanding of 12 March 1975 (and its successor) as applicable to the Executive Secretary, DOD-IDA Management Office, OUSDRE, with a copy to the sponsor or his project officer, as appropriate. Changes in this task will be made only with the approval of appropriate cognizant DoD officials.

b. This task will be conducted under Industrial Security Procedures in the IDA area. If certain portions of the task require the use of sensitive information which must be controlled under military security, the DOD-IDA Management Office will provide supervised working areas in which work will be performed under military security control.

c. A "need to know" is hereby established in connection with this task and access to classified documents and publications and security clearances necessary to complete the task will be obtained through the DOD-IDA Management Office unless otherwise instructed. Report distribution and control will be determined by the sponsor.

James B Statler

JAMES B. STATLER
Colonel USA
Director
DOD-IDA Management Office

FOR IDA: Alexander H Flax
ALEXANDER H. FLAX
President, Institute for Defense Analyses

DATE: April 8, 1982

APPENDIX B

STUDY PROCESS OVERVIEW

APPENDIX B
STUDY PROCESS OVERVIEW

A. INTRODUCTION

This volume integrates the extensive study efforts of a large-scale technology analysis and case study analysis activity and provides findings and recommendations with associated implementation plans for improving weapon system readiness through innovative program structuring and integration of new and advancing technology.

The study was done for OASD (MRA&L) and USDR&E, with Mr. Russell Shorey (MRA&L) serving as the Department of Defense point of contact.

The results presented in this and other volumes are those of one of the largest study efforts ever focused on readiness through R&M. The study could only have been done with the extraordinary leadership and support of personnel of the Office of the Secretary of Defense, the military services, government, industry, and academia.

B. BACKGROUND

As a result of the 1981 Defense Science Board Summer Study on Operational Readiness, Task Order T-2-126 was generated to look at potential steps toward improving the Material Readiness Posture of DoD (short title: R&M Study). This task order was structured to address the improvement of R&M and readiness through innovative program structuring and applications of new and advancing technology. This Volume integrates analysis relative to Volume III, program structuring aspects, and Volume IV, new and advancing technology aspects of readiness.

C. OBJECTIVE

The study objective is defined in Task Order T-2-126 as follows:

> "Identify and provide support for high pay-off actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvements in R&M and readiness through innovative uses of advancing technology and program structure."

D. SCOPE

The scope of this study, as defined by the task order, is:

> "To (1) identify high pay-off areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M or readiness through innovative uses of advancing technology."

E. APPROACH

The objective of the overall study was to produce meaningful and implementable recommendations, substantiated by quantitative data and implementation plans.

1. Overall Approach

To accomplish the overall objective, emphasis was placed on the elucidation and integration of the expert knowledge and experience of engineers, developers, managers, testers, and users involved with the complete acquisition cycle of weapon system programs, as well as on supporting analyses. A search for a study director was conducted through major industrial companies, a director was selected, and the following general plan was adopted:

General Study Plan	Results In Documents
• Present new concepts to DoD with implementation plan and recommendations for application.	Vol. I
• Analyze and integrate review results.	Vol. II
• Develop, coordinate and refine new concepts.	Vol. II
• Select, analyze, and review existing successful programs.	Vol. III
• Analyze and review related new and advanced technologies.	Vol. IV

The approach to implementing the plan was based on an executive council core group for organization, analysis, integration, and continuity. Extensive use was made of working groups, with heavy military and industry involvement and participation, and coordination and refinement through joint industry/Service analyses and review. The overall study organization is shown in Fig. B-1.

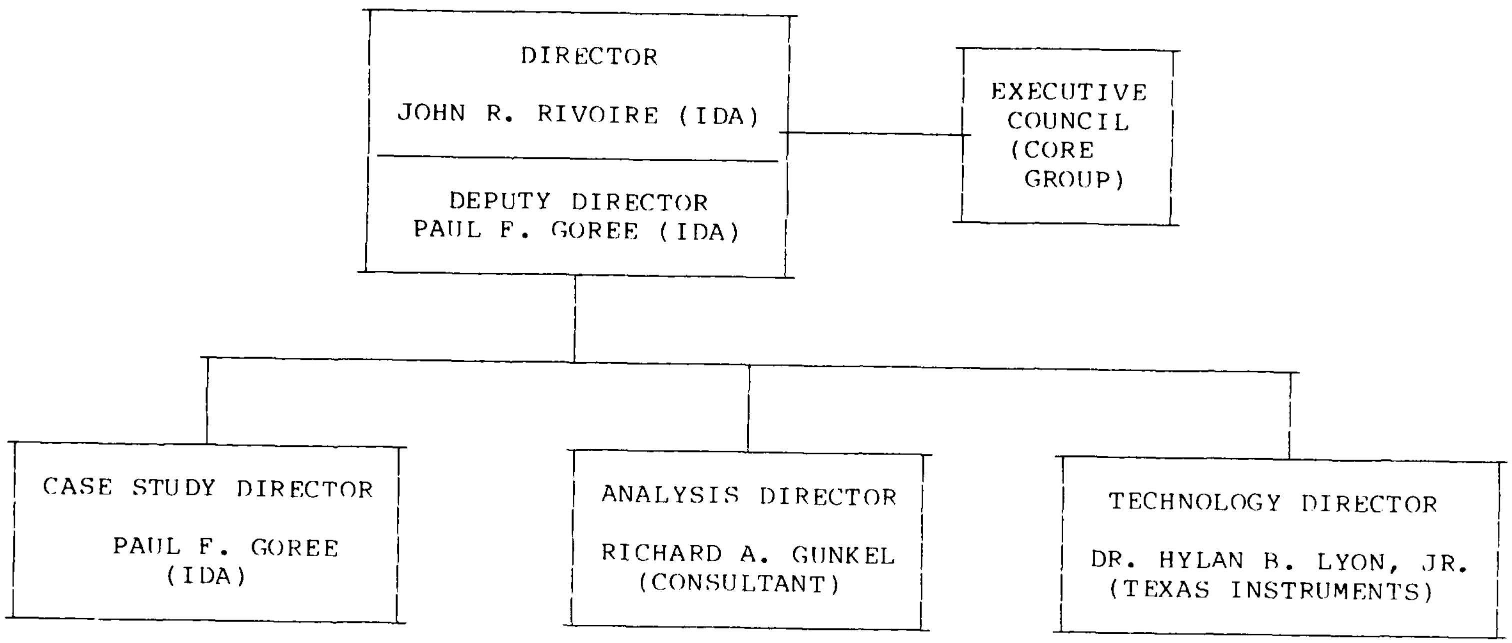

FIGURE B-1. Study Organization

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The study was divided into five phases. Phase 1 was focused on the organization and planning aspects of the study, Phase 2 on the technology and case study reviews, Phase 3 on the analysis and integration of data, Phase 4 on DoD review, and Phase 5 on areas for consideration in follow-on activity.

2. Executive Council

An executive council core group was established in July, 1982. Members consist of:

INDUSTRY PARTICIPANTS

Booton, William C.	General Dynamics
Danielson, Oliver F.	McDonnell Douglas
Edwards, James P.	Gould, Inc./DED
England, Gordon R.	General Dynamics
French, Carl H.	Boeing Aerospace Co.
Giles, Jack A.	Texas Instruments, Inc.
Karr, Charles H.	Westinghouse Electric Corp.
Kern, George A.	Hughes Aircraft Co.
Krantz, Frank M.	Westinghouse Electric Corp.
Lavery, Jack V.	Martin Marietta Corp.
Lyon, Dr. Hylan B., Jr.	Texas Instruments, Inc.

MILITARY PARTICIPANTS

Burnette, Howard E.	US Army/Logistics Center
Clouse, LCDR Paul	Office of Chief of Naval Operations
DeLauche, Maj. John S.	HQ USAF/RDPT
Duff, James B	Naval Operational Test and Evaluation Force
Griffin, LTC Larry D.	HQ AFALD/PTR
Hergenroeder, Maj. Bob	HQ USAF/RDCS
LaSala, Kenneth P.	HQ Naval Material Command
Light, Harry	US Army Materiel Development & Readiness Command
Lowell, Capt James R.	HQ AFTEC/LGL
Neff, Robert	HQ AFSC/ALK
Nordstrom, Arthur H.	US Army Materiel Development & Readiness Command

Paige, Maj Alan	HQ AFSC/ALK
Urban, Louis, J.	ASD-AFALD/AX
Westcott, Edmund J.	HQ AFSC/CCK

OSD SPONSORS

Burchfield, Del	OUSD(R&E)
Contos, Dr. George A.	OASD(MRA&L)
DeLauer, Dr. Richard	USD(R&E)
Gibson, Lt Col Paul S.	OASD(MRA&L)
Gilleece, Mary Ann	OUSD(R&E)
Greene, Kurt	OUSD(R&E)/DMSSO
Korb, Dr. Lawrence J.	ASD(MRA&L)
Larimer, Col Walker A.	OUSD(R&E)/DMSSO
Long, William	OUSD(R&E)
Meth, Martin A.	OASD(MRA&L)
Mittino, John A.	OUSD(R&E)
Shorey, Russell R.	OASD(MRA&L)
Stimson, Dr. Richard A.	OUSD(R&E)
Webster, Dr. Richard D.	OASD(MRA&L)

IDA PARTICIPANTS

Goree, Paul F.	IDA R&M Study Deputy Director
Rivoire, John R.	IDA R&M Study Director

PART-TIME CONSULTANTS

Gates, Howard P.	IDA Consultant (Independent)
Goldstein, Siegfried	IDA Consultant (Siegfried Enterprises, Inc.)
Gunkel, Richard A.	IDA Consultant (Independent)
Kunznick, Gene A.	IDA Consultant (Independent)
Musson, Thomas A.	IDA Consultant (Evaluation Research Corporation)

One- or two-week meetings were held monthly at IDA for the duration of the study.

3. Case Study Approach

The basic case study approach was to build a foundation for analysis and to analyze the front-end process of program stru‹ ıring for ways to attain R&M, mature it, and improve it. Concurrency and resource implications were considered. Tools to be used to accomplish this were existing case study reports, new case studies conducted specifically to document quantitative data for cross-program analysis, and documents, presentations, and other available literature. In addition, focused studies for specific technology implications were conducted by individual technology working groups and documented in their respective reports. To accomplish the new case studies, the organization shown in Fig. B-2 was established.

In some areas where program documentation and records did not exist, the actual experience and judgment of those involved in the programs were captured in the case studies. Likewise, in the analysis process, the broad base of experience and judgment of the military/industry executive council members and other participants was vital to understanding and analyzing areas where specific detailed data was lacking.

4. Case Study Participants

Without the detailed efforts, energies, patience, and candidness of those intimately involved in the programs studied, this case study effort would not have been possible within the time and resources available.

Participants making major contributions to this massive effort are listed on the following pages.

In addition to the listed participants, candid comments and inputs were received from personnel from many other programs, including generals, admirals, and Senior Executive Service personnel.

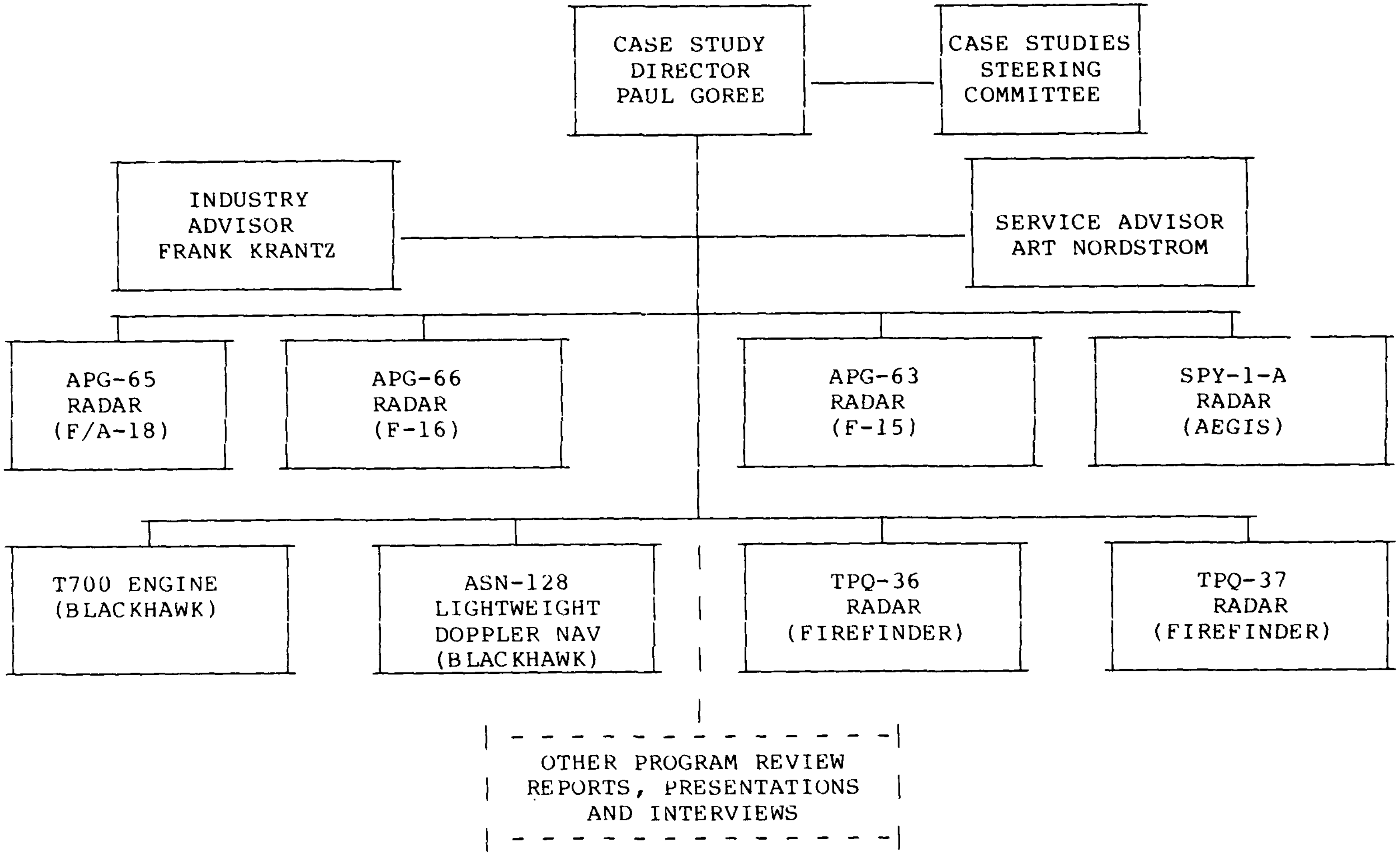

FIGURE B-2. Case Study Organization

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Case Study Participants:

Bailey, E.W.	McDonnell Douglas
Boiles, J.H.	McDonnell Douglas
Booton, Bill	General Dynamics
Brooks, C.R.	Army
Butler, Norman	General Dynamics
Cutchis, P.	IDA
Danielson, O.F.	McDonnell Douglas
Dobyns, Dick	Westinghouse
Eikerenkoetter, J.	McDonnell Douglas
Fahey, J.R.	McDonnell Douglas
Farrell, C.F.	Hughes Aircraft Co.
Fisher, G.	McDonnell Douglas
Galanti, Carl	AVRADA
Gebhardt, C.C.	Hughes Aircraft Co.
Gibson, LTC P.S.	OSD/MRA&L
Goldstein, S.	IDA Consultant
Goree, Paul F.	IDA (Case Study Director)
Griffin, LTC Larry D.	HO AFALD/PTR
Gunkel, Dick	IDA Consultant
Hatfield, Phil	Westinghouse
Job, M.A.	Hughes Aircraft Co.
Johnson, Marvin	General Dynamics
Kamrass, Murray	IDA
Kennedy, P.E.	Hughes Aircraft Co.
Kern, G.A.	Hughes Aircraft Co.
Koon, K.F.	General Electric Co.
Kunznick, G.A.	IDA Consultant
Lanctot, R.	Hughes Aircraft Co.
Lawdel, W.	McDonnell Douglas
Makowsky, Larry C.	DARCOM
McAfee, Naomi	Westinghouse

Case Study Participants, cont'd:

McIntyre, Marlene	DARCOM
Miller, R.M.	Hughes Aircraft Co.
Musson, Tom	IDA Consultant
Nelson, F.B.	Hughes Aircraft Co.
Osifchin, Edward	Singer Kearfott
Pace, W.E.	McDonnell Douglas
Parham, David	General Dynamics
Perkins, C.P.	Hughes Aircraft Co.
Przedpelski, Z.J.	General Electric Co.
Pyle, Roy	Westinghouse
Quinn, John C.	ERADCOM
Rakeman, J.	Hughes Aircraft Co.
Rogger, W.R.	McDonnell Douglas
Russell, Capt. Bob	ASD/YPEZ
Saari, A.E.	Hughes Aircraft Co.
Selling, A.L.	General Electric Co.
Slinkard, J.	McDonnell Douglas
Stevens, R.R.	McDonnell Douglas
Summers, Bill	General Dynamics
Tod, E.	McDonnell Douglas
Venezia, T.E.	Hughes Aircraft Co.
Wellborn, J.M.	General Electric Co.
Widenhouse, Carroll	HQ AFALD/PTR

5. Technology Study Approach

The basic technology study approach was to build a foundation for analysis and to analyze areas of technology to surface: technology available today which might be applied more broadly; technology which requires demonstration to finalize and reduce risk; and technology which requires action today to provide reliable and maintainable systems in the future. Program structuring implications were also considered. Tools used to accomplish this were existing documents, reports, and study efforts such as the Militarily Critical Technologies List. To accomplish the technology studies, sixteen working groups were formed, and the organization shown in Fig. B-3 was established.

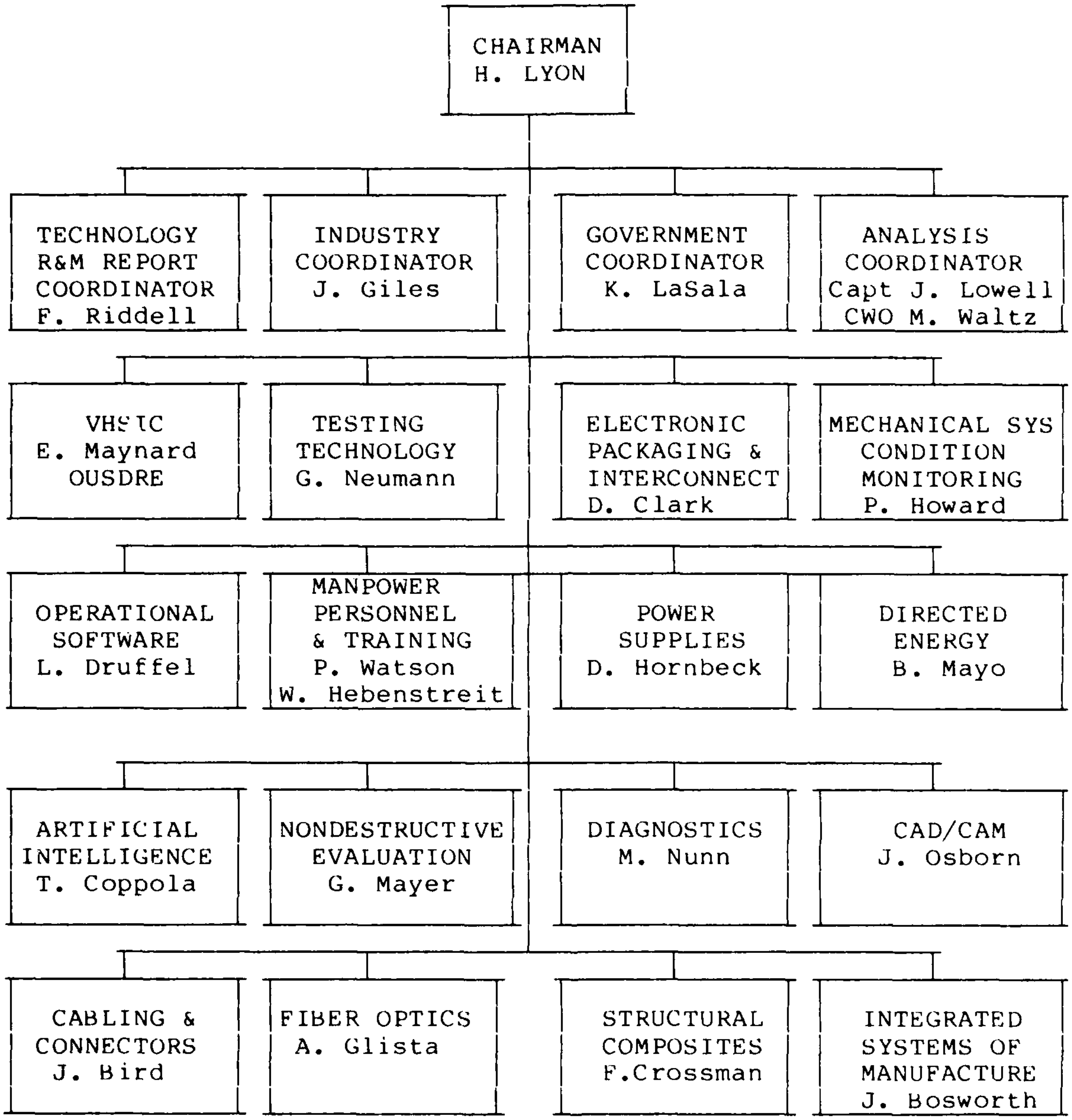

FIGURE B-3. Technology Steering Committee

6. Technology Study Participants

Without the detailed efforts, energies, patience, and candidness of those intimately involved in the technologies studied, this technology study effort would not have been possible within the time and resources available.

Participants making major contributions to this massive effort are listed on the following pages.

In addition to the listed participants, candid comments and inputs were received from personnel from many programs, including generals, admirals, and Senior Executive Service personnel.

Technology Study Participants:

Ahouse, Dr. D.	AVCO
Alloway, Francis E.	General Dynamics
Argento, Dr. Joseph M.	Army DRDAR-OAS
Asman, Peter	NAVSEA
Augl, Joseph A.	Naval Surface Weapons Ctr.
Bareford, Robert	Northrop Corp.
Behnen, George M.	Army DADAV-O
Bird, Joe	Martin Marietta Bosworth,
Blackbrn, Eugene	RADC
Bosworth, Joe	RB Robot Corp.
Breland, Maj. John	Air Force HQ AFSC/DL
Broz, Alan	AMMRC
Ciccio, Joseph	Raytheon
Clark, Richard J.	General Electric
Conroy, John T.	Army DADAV-O
Cooper, Dr. Thomas	Air Force AFWAL/ML
Coppola, Tony	RADC
Crossman, Dr. Frank	Lockheed
Davis, Walter	Boeing
Dexter, H. Bensen	NASA/Langley Research Ctr.
Dorgan, CMS John F.	Air Force SA-ALC/MMEI
Finn, Paul	Sikorsky A/C
Foltz, John	Naval Air Systems Cmmand
Foutz, Gerrold	FOUTZ
Freedman, Dr. J.	MIT/LL
Gardner, Dr. James	Honeywell
Garrett, Ray	McDonnell Aircraft Co.
Gause, Lee W.	Naval Air Development Ctr.
Giles, Jack	Texas Instruments
Giordano, Paul	GIORDANO
Glista, Andy	Naval Air Systems Comm d

Technology Study Participants, cont'd:

Green, Dr. Robert E.	Johns Hopkins University
Halpin, Bernard	Army DRXMR/OC
Haskins, James F.	General Dynamics
Hatch, Harold P.	Army DRXMR-S
Hebenstreit, Wolf	Boeing
Herr, J.C.	General Dynamics
Hess, Andy	NASC
Hornbeck, Don	EG&E
Horton, Ray	Boeing
Howard, Paul	TEDECO
Hudgins, Wayne	AVARDCOM
Katz, Rod	Naval Avionics Center
Kedzior, Chester T.	Army DRSTA-OAT
Klapper, E.	Hughes
Konsowski, Stephen G.	Westinghouse
Labor, James	Northrop Corp.
Lacedonia, Daniel	Hamilton Standard
Lasala, Ken	USN
Lee, Dick	USN
Lewis, W.H.	Lockheed
Light, Harry L.	Army HQ DARCOM
Linder, Steve	NASC
Lowell, Capt. Jim	USAF
Lyon, Hylan B.	Texas Instruments
Mayer, Dr. George	ARO
Maynard, Egbert (Sonny)	OSDR&E
Mayo, Bruce	Sperry
McGillivary, Duncan	USN
McKee, Dean	NOSC
Meade, L.E.	Lockheed-Georgia
Merriman, Steve	NADC
Metcalf, Doug	Essex

Technology Study Participants, cont'd:

Meth, Martin	OASD
Miller, Dr. J.	TRW
Mitchell, Tom	Research Triangle
Muckler, Dr. Fred	Canyon
Mullineaux, James L.	Air Force AFWAL/FIBC
Mulville, D.R.	Naval Air Systems Command
Nawrocki, Dr. Leon	ARI
Neumann, George	Giordano
Nicholas, Jack R.	Naval Sea Systems Command
Norton, Bryan A.	Batelle Columbus Labs
Nunn, Mel	Naval Ocean Systems Ctr.
O'Neill, Dr. Harry	ARI
Orlansky, Dr. Jesse	IDA
Osborn, Jack	Structural Dynamics
Pearson, Dr. J.	UTRC
Phifer, Maj. Lonnie D.	Air Forec SA-ALC/MMEI
Pratt, Isaac	ERADCOM
Prokop, Jon	Texas Instruments
Reifsnider, Kenneth	Virginia Polytechnic Inst.
Renton, James C.	Vought Corp.
Rice, Ray W.	Naval Research Lab
Robbins, Maurice	IBM
Roderick, Dr. George L.	Army AVRADCOM
Rosen, Ken	Sikorsky
Sandow, Forrest	Air Force AFWAL/FIBAC
Sendeckyj, George	Air Force AFWAL/FIBE
Shapery, Richard A.	Texas A&M University
Shapiro, Homer	Hughes
Shaw, William	MPS
Sicilia, Dr. Thomas	DSAD
Singleton, William	
Soderquist, Joseph	Federal Aviation Adm.

Technology Study Participants, cont'd:

Spitzer, Hermann, J.	MFRADCOM
Springer, George	University of Michigan
Squires, Steve	OUSDR&E
Starnes, James H.	NASA/Langley Research Ctr.
Stellabotte, Michael L.	Naval Air Development Cmd.
Stone, Robert	Lockheed-California
Tsai, Stephen W.	Air Force AFWAL/MLBM
Unger, Robert	AET
Urban, Richard	General Electric
Vestewig, Dr. Richard	Honeywell
Watson, Paul	Hughes
Weddle, Peter	DRC
Wilkins, Dick	General Dynamics-Ft. Worth
Williams, Mike	
Wolpin, M.	Bell
Wright, John C.	General Electric
Zimmerman, Dan	ISBM

7. Additional Participation

The military services, universities, and over 100 companies provided support for the study. Over 300 meetings were held encompassing technology working groups, case study working groups, and conferences with industrial groups, senior military officers, and government and industry executive personnel.

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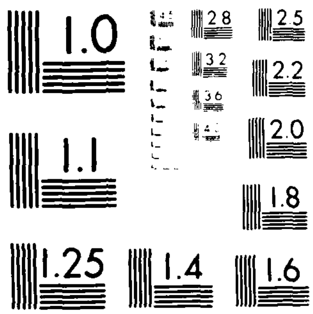
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APPENDIX C

DRAFT ARMY ACTION PLAN

APPENDIX C

DRAFT ARMY ACTION PLAN

A. PURPOSE

This plan defines actions and assigns organizational responsibility for implementing the high-payoff actions identified by the OSD Reliability and Maintainability (R&M) Study to achieve quantum improvements in performance and readiness of future and fielded Army systems and equipment. This plan, when approved, will be incorporated into the thrusts for DARCOM Directions (D^2).

B. OBJECTIVES

The objectives are to achieve a quantum improvement in performance to provide the capability to conduct dispersed operations for long periods of time with minimal maintenance (AIRLAND 2000) and to achieve this performance at reduced acquisition and support costs.

C. HIGH-PAYOFF ACTIONS

1. <u>Structure the Technology Base to Provide Mature Technology for Future and Fielded Systems (DRCLD Lead)</u>.

Technical analyses will be conducted by the appropriate laboratory to determine the underlying causes of failure. Technology developments will be identified, road maps (funding and schedule) developed, prioritized, and target systems for demonstrations will be identified. These technology programs will be presented as a

part of the command's program presented annually at the RDT&E Review and included in the yearly DARCOM Science and Technology Long Range Plan beginning FY 1985. (D^2 Thrust: #4 Long Range Research and Acquisition Plan.)

2. Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) Reliability and Maintainability (R&M) Modules (DRCMT Lead).

A CAD system will be developed and implemented that will assure the consideration of R&M as an ongoing process in the design phase. A CAM system will be developed and integrated with the CAM system to assure that R&M design features are retained in the manufacturing process.

3. Improve Information for Performance Improvement/Cost Reduction Projects (DRCSM Lead).

Information to guide technology base development, new systems development and product improvement of materiel will be collected/ assembled and stored in a single DARCOM data base, The Deficiency Reporting System (DRS). The DRS will contain data from all appropriate sources such as the Sample Data Collection, Equipment Improvement Recommendation Program, Logistics Assistance Program, screening of support items consumed, and field liaison, post fielding, or fielded systems visits/reviews. The principal performance indicator (benefit) from this data base is as follows: the percentage of deficiency reports resulting in engineering changes having performance improvement/ cost reduction as their objective. This system will be operational by first quarter FY 1985. (D^2 Thrust: #9 Customer Support.)

4. Structure Acquisition Programs to Optimize Performance (DRCOA Lead; DRCDE Support).

A structure will be developed and implemented in DARCOM programs which will provide for front-end planning and activities for elements of RAM design, RAM growth and environmental stress screening. Current procedures will be reviewed, regulations changed and interim policy provided, training conducted, and applications to current programs scheduled. (D^2 Thrust: #21 Product Assurance Improvement.)

5. Work Force Improvement (DRCPT Lead).

Training programs in RAM for DARCOM managers and engineers will be improved. An operational concept and resources plan to strengthen the RAM curriculum will be prepared (D^2 Thrust: RESHAPE.)

C. FUTURE ACTIONS.

Directorates designated as lead will develop and implement detailed plans for the above high-payoff actions. A workshop will be conducted to coordinate activities and a status briefing will be presented to the DARCOM Command Group. Where necessary, adjustments will be made to the POM.

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